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Productivity Shocks and National Food Security for Japan

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Productivity Shocks and National Food Security for Japan*

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Abstract

Agriculture is the focus of much contention in free trade negotiations. The Japanese government is against liberalizing the rice trade on the grounds that it would threaten "national food security" in the events of such shocks as crop failure, war, and embargo. Trade liberalization is expected to make Japan more dependent upon food imports and to make the Japanese economy more susceptible to these risks. Using a stochastic computable general equilibrium model, we conducted Monte Carlo simulations to quantify impact of rice productivity shocks and export quotas by major rice exporters to Japan and found little chance for trade liberalization for Japan to suffer from such shocks.

JEL Code: C68, D24, Q17, Q18
Keywords: agricultural trade and protection; food security; productivity shocks; self-sufficiency rate of foods; emergency stocks

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1. Introduction

The food self-sufficiency rate has been a key focus of debate on Japanese agricultural policy. Japan's food self-sufficiency rate is merely 40% on a calorie basis, a significantly lower rate than those of other major developed countries. While this low food self-sufficiency rate is a result of the outstanding comparative advantage of Japan's industrial sectors, it brings a concern that food shortages may be caused by unexpected events such as crop failure, war, and embargo. Bad weather in 1993 reduced the country's rice harvest by 25% compared with the average yield, which is the second worst year on record since 1926.[1] There was a soybean embargo due to a serious crop failure in the US in 1973 and a grain embargo in response to the USSR's invasion of Afghanistan in 1980.

These unexpected events made the Japanese government aware that excessive dependency on imports for food supply is a risk factor for Japan's "national food security." The central question involved in ensuring national food security is how to secure food consumption despite such uncertainties of food production and supply in Japan.[2]

1.1 National Food Security and Japan's Agricultural Policy

The Ministry of Agriculture, Forestry, and Fisheries (MAFF) (2006) established a contingency plan to secure the food supply for domestic consumption in emergency situations. This plan was put into place to achieve national food security as defined in the Food, Agriculture, and Rural Areas Basic Act, which had been revised the year before. MAFF supposed that the minimum calorie intake in emergency situations should be 2,000 kcal/person/day, which is about 20% less than usual, and defined two cases depending on the

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[1] The worst year took place in 1945 with a 33% decline.

[2] This "national food security" is a unique concept compared with the popular concept of "food security," which is often discussed in the context of economic development under increasing population and continuing poverty. Hayami (2000) clarifies their difference.

seriousness of the situation: (a) the emergency case, where supply of all the major crops is not enough to support the minimum calorie intake defined as 2,000 kcal/day/person, and (b) the warning case, where supply of one of the major grains is anticipated to be 20% less than usual. The plan includes several measures to be implemented based on the emergency levels, such as promoting domestic production, managing emergency stocks, and controlling food markets. Among crops, rice is the most important commodity for Japan. Rice composed 28% of the total calorie intake, followed by wheat, which contributed 13% of the total calorie intake in 2001.[3] The government keeps large emergency stocks of rice—as much as 2.5% of annual rice production—and other major crops to secure the food supply, while making continuing efforts to increase the country's food self-sufficiency rate.

High trade barriers on rice have played an important role in the achievement of an almost perfect self-sufficiency rate for rice. Proponents of these trade barriers argue that they are necessary to maintain the overall self-sufficiency rate of food because the supply of the other foods depends heavily on imports. Even though trade theories tell us that gains from rice trade could be considerable, proposals for free trade of rice have never been accepted in Japan because free trade lowers the self-sufficiency rate of food, thereby increasing the dependency of the food supply on imports and making the food supply less secure. We ask whether it is reasonable to sacrifice gains from trade for the sake of national food security and to what extent national food security can be achieved by protecting the domestic market.

When we critically examine the popular views on this food security issue, it is obvious that Japan's rice production (not consumption) is highly dependent on imports, particularly for its input of oil and its products. As Wailes *et al.* (1993) pointed out, it is essential to consider energy security issues in order to have a realistic discussion about Japan's national food security. However, this would make our analysis extremely

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[3] Source: FAOSTAT <URL:http://faostat.fao.org/>.

complicated because the causes of oil-related shocks often include political issues and crises as well as speculation in commodity markets. The probability of these shocks is difficult to estimate, so we cannot reach any conclusion about such estimates or move into the stage of empirical analysis on the food security issues. (Similar arguments can be applied to export bans or restrictions, which are often triggered by political reasons, e.g., to maintain access to cheap food for people in grain-exporting countries.) Instead, it is productive for us to directly examine the validity of the central grounds of Japan's agricultural policy for national food security—even if these grounds may be an invention of agricultural protectionists to protect the domestic market. In our examination, we will thus consider the various risk factors conceived by those agricultural protectionists.

The impact of agricultural trade liberalization is two-fold: (1) deterministic efficiency improvements by removal of trade barriers and (2) stochastic gains and losses from productivity shocks, whose magnitude can be exacerbated or mitigated depending on trade openness. Researchers have often analyzed the first aspect of trade liberalization but have rarely examined the second aspect. This lack of analysis of the second aspect sometimes causes people to be uninformed and oppose trade liberalization simply because trade liberalization is generally believed to make the domestic economy susceptible to shocks from abroad.

1.2 Rice Trade and its Barriers

Japan has strictly prohibited imports of rice but recently permitted minimum access (MA) import of rice in 1995 and its tariffication in 1999 as a part of the Uruguay Round (UR) agreements. The permitted amount is, however, only 786 thousand tons, which is equivalent to 8.7% of domestic production in 2001. The effective trade barrier is estimated to be several hundred percent (Table1). If this trade barrier is abolished, imports are expected to have a very high share in the total rice supply.

Japan's rice consumption is concentrated upon mid- or short-grain rice (so-called japonica rice), rather than long-grain rice. The former type of rice is strongly preferred in East Asian countries; the latter type is popular elsewhere in Asia and in other countries. Japan's rice trade patterns reflect this preference. Japan's three major rice trade partners (China, the US, and Australia) produce japonica rice and expect to increase their exports to Japan after the rice trade is liberalized.

As rice in many countries is mostly produced and consumed domestically, rice trade is thin: only a small fraction of domestic production is exported and imported internationally. This characteristic for rice shows a clear contrast to other major agricultural commodities like wheat. The top ten rice-producing countries cover almost 90% of the world's total production of rice (Table 2). They are mostly Asian countries where high temperatures and high humidity dominate. Their production fluctuates based mainly on weather conditions. Droughts, cool summer days, and cyclones/typhoons significantly damage rice production. While productivity seems to have an upward-sloping trend, it sometimes shows sudden drops (Figure 1). As mentioned above, Japan experienced a 25% drop in rice yield in 1993.

Once we liberalize the rice market of Japan, any shocks in the domestic and foreign markets will directly affect such a thin international market. Furthermore, taking account of Japan's strong preference toward japonica rice, the international market seems much less reliable as an alternative supply source for Japan. Such facts about international rice markets seem to support the idea that the national food security has to be established only by protecting the domestic rice market for its high self-sufficiency rate, rather than by depending on foreign supply sources.

1.3 Literature Review

One of the most important issues for Japan's agricultural policy has been implementation of the UR agreements. Japan has never regularly imported rice but had to accept the MA imports, allowing imports to provide for as much as 4% of the country's domestic consumption from 1995 on. The MA imports were scheduled to increase up to 8% by 2000 if Japan did not accept tariffication of barriers on rice imports. As Japan had a strong excess supply pressure due to the rice production subsidy and the declining trend of rice consumption, the MA imports were expected to exacerbate the imbalance significantly, as Kako *et al.* (1997) projected.

After accepting the MA rice, the next issue was whether Japan should accept tariffication of rice imports or continue increasing the MA imports up to 8% of domestic consumption. By accepting tariffication, Japan could decelerate the influx of foreign rice. Hayami and Godo (1997) investigated politically feasible combinations of policy measures of the MA imports, tariffication, and acreage control. Cramer *et al.* (1999) found that Japan would have three million tons of rice imports (about one-third of domestic consumption) when assuming an 8% annual tariff reduction after the tariffication of non-tariff barriers. In the conclusion, they suggested that food security could be improved by increasing accessibility to the international markets rather than by protection but did not explicitly answer our question of whether or not the international markets could be reliable considering fluctuating productivity in and outside Japan.

Cramer *et al.* (1993) found a removal of direct and indirect trade barriers of rice in all countries would lead to increases of Japan's rice imports by about five million tons. Wailes (2005) did a similar but updated analysis for elimination of tariffs and export subsidies and expected about two million tons of rice imports by Japan. These results indicate free rice trade would lead to imports as much as 20–50% of domestic consumption.

South Korea shares a similar situation with Japan regarding strict import protection of rice and food security concerns. Beghin *et al.* (2003) quantified the minimum excess burden to protect South Korea's domestic markets. They found the current protection schemes were significantly inefficient but could not directly analyze the impact of uncertainty of food supply from foreign sources because the risk factors, like food self-sufficiency rates and domestic production, were assumed to be given as the policy targets.

Hosoe (2004) developed a world trade computable general equilibrium (CGE) model to evaluate impact of a domestic productivity shock in 1993 under rice price control in Japan and impact of Japan's emergency rice imports on welfare in other countries. The productivity shock was assumed to be merely deterministic in the sense that its magnitude was calibrated to reproduce the historical event of Japan's bad crop in 1993.

In sum, while strict protection on rice imports is supposed to contribute to enhancing the national food security to guard against unexpected changes in the food supply, few have considered fluctuation or contingent supply shocks in the agricultural sector in order to evaluate the overall benefits and possible losses from trade liberalization. Conventional rice sector analyses have reported a significant degree of import penetration under rice trade reforms but have inferred little about the impact of agricultural productivity shocks transmitted to and from international markets through the liberalized trade.

In assessing the national food security for Japan, we have to consider a wide range of productivity shocks in addition to those experienced so far. As for the location of the shocks, we can expect productivity shocks in all the countries, not only in Japan. Our stochastic world trade CGE model in combination with a Monte Carlo method provides a comprehensive framework to analyze international rice markets under uncertainty. This technique is similar to that used by Harris and Robinson (2001) to analyze the impact of weather fluctuations induced by El Niño on regional agricultural output and income distribution in Mexico. In their model, the productivity of value added was randomized to demonstrate the effects of the agricultural productivity shocks.

In this article, considering both the deterministic gains and the stochastic gains/losses from trade liberalization, we use a stochastic world trade CGE model to determine whether trade liberalization is really beneficial for Japan's national welfare and whether it is a serious risk factor for the national food security. Focusing on the rice sectors in Japan and its rice trade partners, we analyze the impact of the abolition of import tariffs on paddy rice and use a Monte Carlo method to simulate productivity shocks in the paddy rice sector. In addition, we evaluate the effectiveness of the emergency stocks that the Japanese government prepares for use in the event of bad crops and other emergency situations. Moreover, we simulate a rice embargo by major rice exporters to Japan assuming Japan had abolished rice import barriers and completed reallocation of sluggish factors.

This article proceeds as follows. Section 2 describes the model structure; Section 3 explains simulation scenarios. Section 4 discusses our simulation results. Section 5 concludes our analysis with some policy implications.

2. Structure of the World Trade Stochastic CGE model

While using the basic structure of a single-country CGE model described by Devarajan *et al.* (1990), we extend the model to create a multi-country model to analyze international rice markets under uncertainty. Reflecting the fact that rice trade partners for Japan are mostly Asia-Pacific countries (Table 1), we distinguish 12 regions using the Global Trade Analysis Project (GTAP) database version 6.[4] Each region has eight sectors, including five food-related sectors (Table 3). Each sector is represented by a perfectly competitive profit-maximizing firm with a Leontief production function for gross output and with a constant elasticity of substitution (CES) production function for value added (Figure 2). We assume 0.2 for the elasticity of substitution in the agricultural sectors (paddy rice, wheat, and other agriculture) and 1.0 for the other sectors.[5] Among the value added components, capital and land are assumed to be immobile between sectors in order to model relatively short-run phenomena under unforeseen shocks in most simulations discussed

[4] For more information about the GTAP database, see Hertel (1997).

[5] Even when we alternatively assume 0.1 or 1.0 for this elasticity in these agricultural sectors, our conclusions are found to be qualitatively robust, as shown in Appendix.

later. Labor is assumed to be mobile between sectors. International factor mobility is not assumed. These factors are assumed to be fully employed with flexible factor price adjustment.

Sectoral gross outputs are split into domestic outputs and composite exports using a constant elasticity of transformation (CET) function. The domestic goods and composite imports are aggregated into composite goods with a CES function as Armington (1969) assumed. The composite imports consist of imports from various regions; the composite exports are decomposed into exports to various regions. For these CES/CET functions, we use the elasticity of substitution as suggested in the GTAP database. The elasticity of substitution represents the similarity of goods differentiated by origin and destination of trade. For example, the elasticity of substitution between the domestic goods and the composite imports is assumed to be 5.05 for paddy rice and 2.60 for processed rice.[6]

Although we do not explicitly consider the grain types of rice in our model, the nested CES structure approximately reflects Japan's preference for japonica rice. Share parameters in the CES functions are calibrated so as to reproduce the actual trade flows of rice mainly from countries that produce japonica rice. The current account surplus/deficit is set constant in US dollar terms for each region. Exchange rates are flexibly adjusted so that the current account balance holds in all the regions.

The composite goods are used for consumption by the household and the government, investment, and intermediate input. If the commodity is one of the food commodities indicated in Table 3, it is aggregated into a food composite with other food commodities. The food composite contributes to utility (Figure 3). For this food composite aggregation process, we assume a CES function to give flexibility to our assumptions about

[6] As is often assumed, these elasticities are doubled and used for the elasticity of substitution/transformation in the composite imports/exports aggregation functions. Sensitivity analysis is conducted with 30% larger and smaller elasticity for the paddy rice and the processed rice sectors. The results indicate that our findings are qualitatively robust, as shown in Appendix.

price elasticity of food consumption. We assume 0.1 for the elasticity of substitution for the food composite CES function.[7] If the commodity is not a food, it directly contributes to utility. The complete list of the model equations is available upon request.

3. Simulation Scenarios

To quantify the overall impact of Japan's rice trade liberalization on the country's national food security, we consider the following scenario factors: (1) unilateral abolition of trade barriers on paddy and processed rice imports by Japan, (2) fluctuations of productivity in the paddy rice sector, (3) emergency stocks to mitigate the adverse impact of anticipated productivity shocks, and (4) quotas on rice exports imposed by the four major rice exporters to Japan. We set up 11 scenarios to determine how seriously the national food security is jeopardized or ensured by these three scenario factors (Table 4).

The first two scenarios, T0 and T1, are often employed in conventional trade liberalization analysis as the base run and a counter-factual run considering only the abolition of rice import barriers by Japan. The following six scenarios are used to investigate the impact of trade liberalization subject to productivity shocks in Japan (Scenarios J0 and J1), in the rest of the world (ROW) (Scenarios R0 and R1), and all over the world (Scenarios A0 and A1). Scenario S is used to analyze the effectiveness of the emergency stocks the Japanese government prepares to mitigate the impact of adverse productivity shocks in the domestic sector. The last two scenarios, M and Q, are used to evaluate impact of possible export quota imposition by rice exporters. Details of those scenario factors are explained below.

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[7] Generally, the price elasticity of necessities like rice is supposed to be very small. However, there is a variety of rice price elasticity estimates ranging from zero (i.e., not significant) or 0.1 to 2.8. A survey of these parameter estimates and a sensitivity analysis with respect to this elasticity are provided in Appendix. Our simulation results are also found to be qualitatively robust.

3.1 Scenario Factor 1: Abolition of Trade Barriers

We assume unilateral abolition of the tariff and non-tariff barriers by Japan, which are reported by the GTAP database version 6 (Table 1). The tariff rates and tariff-equivalent trade barriers on paddy and processed rice imports generally reach several hundred percent. Neither border barriers in the other sectors nor those in the other regions are assumed to be changed. Abolition of such high trade barriers would increase import penetration to reduce domestic rice production but would bring about gains from trade as conventional trade analyses suggest.

3.2 Scenario Factor 2: Productivity Shocks

We assume that productivity shocks happen randomly in the total factor productivity parameter of the gross output production function in the paddy rice sector. In statistical estimation, we measure the productivity of the paddy rice sector by production per acre of harvested area and normalize the productivity in 2001 to unity. We estimate standard deviations of the productivity of these 12 regions with time series data for 15 years (1990–2004) provided by FAOSTAT while removing the effect of the time trend on the productivity (Table 5). We assume that the productivity of the paddy rice sector in the region r follows independent identically distributed (i.i.d.) normal distribution $N\left(1, \sigma_r^2\right)$ with these estimated standard deviations. We simulate 1,000 Monte Carlo draws for each scenario. Among our 1,000 Monte Carlo draws, Australia is predicted to experience a productivity decline of over 26%, the most severe decline of the group. Australia is followed by Japan. In the other regions, the worst productivity declines are about 10–20%.

Strictly speaking, the indicator of "the production per acre of harvested area" does not exactly measure the productivity changes caused purely by exogenous shocks because farmers can adjust both the numerator and the denominator of this indicator to some extent. Considering forecasted or real weather conditions and their anticipated outcomes in market prices, profit-maximizing farmers may adjust the quantity and types of inputs or change the timing of planting and harvesting. Their efforts would mitigate the direct impact of weather conditions on the markets. If a bad crop is expected to be too serious to recover, they may not exert any further efforts to produce additional crops and may make the bad crop even worse. Although it would be ideal to estimate pure productivity shocks, doing so would make our statistical estimation process and development of the world trade model too difficult. Thus, we simply employ the indicator of the production per acre of harvested area as a proxy variable of the productivity and conduct a sensitivity analysis regarding the estimated standard deviations in Appendix.

When an adverse productivity shock takes place in Japan—whose domestic output is shipped almost only for domestic use—the country's domestic consumption will be reduced but will be partly supported by imported rice. Similarly, when an abundant rice crop is harvested in Japan, the surplus can be absorbed abroad. As rice trade liberalization increases Japan's accessibility to international rice markets, shocks to the country's domestic rice production can be more flexibly managed through imports under free rice trade. In view of statistical distribution of domestic welfare, given the same magnitude of productivity shocks, trade liberalization itself will shift the mean of welfare distribution upward and will decrease the standard deviation of welfare distribution (the upper graph of Figure 4). In this case, whether a productivity shock is negative or positive, trade liberalization will always bring about preferable impact on welfare distribution.

In contrast to these cases with productivity shocks in Japan, when an adverse productivity shock takes place in the rest of the world, particularly in China, the US, and Australia, Japan's imports from these countries will be jeopardized. Rice trade liberalization increases Japan's dependency on imported food and thus can exacerbate the adverse impact of their productivity shocks to Japan. This is the point that agricultural protectionists emphasize. However, if a positive productivity shock takes place in those countries, Japan can conversely gain by the same mechanism. As the productivity parameter, by definition, distributes around the mean of productivity shocks abroad, such productivity shocks as a whole will not seriously deteriorate the *mean* of welfare distribution in Japan but will increase its *standard deviation* while trade liberalization brings deterministic gains through improvements of resource allocation (the lower graph of Figure 4). In this case, without combining the impact of trade liberalization with those of productivity shocks on the distribution of welfare, we cannot immediately judge whether or not trade liberalization is always welfare-improving. Trade liberalization makes the lower tail of the welfare distribution thicker. This implies that welfare is likely to be worse with rice trade liberalization than without it. This could lead to deterioration of overall welfare for those who have (strongly) risk-averse preferences.

3.3 Scenario Factor 3: Emergency Stocks

Preparing emergency stocks is a popular measure used for coping with bad crops. The impact of the rice supply shock in 1993 was exacerbated partly by the government-led restructuring of Japan's food system. The government had significantly reduced its rice stocks to 0.23 million tons, covering 2.5% of the average annual production. After the bad harvest in 1993, the government increased the size of the emergency stocks to 1.5 million tons. While the increased stocks made the food supply more secure, maintaining those stocks was more costly. We have to assess the potential of the emergency stocks to stabilize the domestic market and achieve better national welfare during bad crop periods.

The size of Japan's emergency stocks is assumed to be as much as 1.5 million tons. This is the amount officially kept by the Japanese government and is equivalent to about 17% of Japan's annual production in 2001. We assume that this emergency stock is released only when a negative productivity shock takes place in Japan so as to maintain the original amount of the domestic paddy rice supply. When the losses of paddy rice production exceed the size of emergency stocks prepared in advance, the market mechanism starts to work with a flexible price adjustment and begins to increase imports. The emergency stocks truncate a part of the lower shoulder of the distribution of the rice supply (Figure 5).

For the simplicity of our comparative statics, we assume that the emergency stocks were prepared before the shocks and that the release of the emergency stocks does not bring any capital gains or losses to the government. By subtracting the storage costs of the emergency stocks from their expected social benefits measured with a welfare indicator, we can quantify the net benefits of the emergency stocks.

Although one of the largest agenda items in the Doha round trade negotiation is reduction of agricultural trade barriers, particularly in developed countries, further than that achieved in the UR, it will take several more years to conclude the negotiation. In the meantime, the government will not liberalize the domestic rice market soon. Thus, in this particular Scenario S, we do not assume any trade liberalization but only productivity shocks all over the world to evaluate the effectiveness of the current stock size.[8] By comparing the simulation results of Scenario A0 with those of Scenario S, we can quantify the benefits of the emergency stocks. Among the 1,000 draws in our Monte Carlo simulation, 493 cases are expected to bring about negative productivity shocks in Japan. The emergency stocks are found to be large enough to fully cover the lost rice yield in 95% of those negative productivity cases.

3.4 Scenario Factor 4: Export Quotas

While productivity shocks jeopardize the rice supply every year, export bans could bring about damage to Japan—as protectionists often worry. This damage could be particularly serious if Japan commits to rice imports and has completed reallocation of sluggish factors (capital and land) from the paddy rice sector to the other sectors in response to changes in rice prices induced by the trade liberalization. To depict such a mid- or

[8] If we assume rice trade liberalization simultaneously, we would have a better welfare outcome in its mean and its standard deviation, as the previous simulation results have shown.

long-term equilibrium after completion of factor reallocation, we first compute an equilibrium assuming rice trade liberalization *with* inter-sectoral mobility of capital and land as well as labor. As the price gap between the domestic and international rice markets indicates, factors originally employed by the paddy rice sector will move out to other sectors. Using this equilibrium as a new reference equilibrium—let it be referred to as the intermediate equilibrium—and simulate productivity shocks without (Scenario M) and with export quotas set by the four major rice exporters to Japan (Scenario Q), where we again prohibit inter-sectoral mobility of capital and land (but allow labor mobility) as Figure 6 indicates.

As the paddy rice sector in Japan would have already contracted more seriously in the intermediate equilibrium, Japan would be found more vulnerable to shocks and export quota imposition in the rice sector. The size of the export quota is assumed to be as large as the original MA import level.

4. Simulation Results

We simulate random productivity shocks and various policies and quantify the costs and benefits of trade liberalization for Japanese economy. Their simulation results are summarized as follows.

4.1 Deterministic Impact of Trade Liberalization

When we assume abolition of all the tariff and non-tariff barriers on paddy and processed rice imports by Japan (Scenario T1), we obtain intuitive results (Table 6). Imports of paddy and processed rice would surge to reduce Japan's domestic production of paddy rice by 49%. This would result in a significant decline of the self-sufficiency rate of rice from 94% to 73%. Rice consumption would be increased by 10% due to consumers exploiting the price decrease of rice. As a result, overall welfare impact measured with equivalent variations (EV) would be 6,749 million US dollars, which is 0.17% of Japan's GDP (Table 7). Most other

Asia-Pacific countries would also gain. China would, however, suffer slightly by increasing its rice exports at the sacrifice of its rice consumption, because rice accounts for a large share of total food consumption but is assumed to be little substitutable with other foods in our CGE model[9].

4.2 Productivity Shocks in the Rest of the World

People are often concerned that when we are heavily dependent on foreign supply sources for rice, the food supply could be insecure due to unforeseen productivity shocks in other countries. When we carry out Monte Carlo simulations with Scenarios R0 and R1 and compare their results with those of Scenarios T0 and T1, we can determine whether or not these concerns are reasonable. The results of Scenario R0 show no change from those of Scenario T0 in the mean of Japan's EV but do show some change in its volatility (Table 8, Figure 7).[10] The welfare distribution of Scenario R0 (and Scenarios J0 and A0, discussed later) indicates that there would be no statistically significant chance for Japan to attain the deterministic gain (as much as 6,749 million US dollars) achieved in Scenario T1 without liberalizing rice imports.

Abolition of trade barriers on rice imports would increase the penetration of foreign rice and lower Japan's rate of self-sufficiency for rice. Imports are subject to productivity shocks abroad. This situation is described by Scenario R1. Its simulation results show that trade liberalization would increase both the mean and the standard deviation of EV compared with those of Scenario R0 (Table 8, Figure 7). This increase of the volatility itself is often regarded as a risk factor for Japan but would not be so large that it could provide a statistically significant chance for Japan to suffer negative welfare impact. Furthermore,

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[9] Note that the elasticity of substitution in the food composite is assumed to be as small as 0.1.

[10] The EV is found to be slightly negative in Scenarios J0 and A0, where we assume only productivity shocks. This is due to the concavity of the utility function, which implies risk-averseness of preference represented by the nested CES utility function.

even if the worst case in terms of welfare came true, the welfare level achieved under free rice trade in Scenario R1 would be better than the welfare level without free rice trade in Scenario R0.

The impact of foreign-made productivity shocks can be confirmed by examining import prices for Japan (Figure 8). While the impact of rice trade liberalization would be overwhelming and would decrease the import price of processed rice by about 80%, the fluctuations of the import price of processed rice seem to be almost nil. As we assume small elasticity of substitution (=0.1) in the food composite CES function, the household's rice consumption would not show any visible fluctuations (Figure 9).

4.3 Productivity Shocks in Japan

When we assume productivity shocks in Japan, the value of trade liberalization under productivity shocks can be assessed from a different viewpoint. The simulation results of Scenario J0 show that productivity shocks in Japan without trade liberalization would bring about significantly large volatility of EV (Table 8, Figure 10). This is because the domestic market is isolated from alternative supply sources in foreign countries due to high trade barriers.

Given the productivity shocks in Japan, the trade liberalization would bring the country a double-dividend (Scenario J1). That is, the mean of EV would increase, but its volatility would decrease. This implies that a higher welfare level would be achieved more securely by trade liberalization. By integrating the domestic market with foreign ones, we can pool the risk of productivity shocks internationally. As the welfare distribution in Scenario J1 shows, there would be no possibility that Japan would be worse off under free rice trade than it is under the status quo.

4.4 Impact of Productivity Shocks All Over the World

Comparing the simulation results of Scenarios R0, R1, J0, and J1, we find that the impact of productivity shocks in Japan would be the dominant factor for its economy. Thus, when we assume random productivity shocks all over the world with and without trade liberalization, the simulation results of Scenarios A0 and A1 would be similar to those of Scenarios J0 and J1, respectively (Table 8, Figure 11). These results do not support the idea that trade liberalization—even under uncertainty of productivity shocks—would be a risky policy for the Japanese economy.

While we have described distributions of EV, we can also obtain distributions for consumption of rice and other foods, which imply calorie intake (Figure 12). Rice trade liberalization would increase the mean of calorie intake but would decrease its volatility. Finally, none of these simulation results indicate any serious food shortages defined as the warning level (20% less supply of a certain food) or the emergency level (calorie intake lower than 2,000 kcal/day/person).

4.5 Effectiveness of Emergency Stocks

Releasing the emergency stocks in bad crop situations in Scenario S, the upper tail of the price distribution would become thinner (Figure 13). The highest price of processed rice would be 1.17 in Scenario S, while it would be 1.37 in Scenario A0. The distribution of rice consumption would be negatively skewed by the release of emergency stocks (Figure 14).

The release of emergency stocks seems to succeed in stabilizing the domestic market and securing the rice supply. However, the overall welfare impact would not be so remarkable. The emergency stocks would increase the mean of EV by 108 million US dollars, compared with the result of Scenario A0; the volatility of EV would not be decreased markedly (Table 8, Figure 15).[11]

[11] If we double the assumed standard deviation of the paddy rice productivity distribution in all the regions, the benefit of the emergency stock would reach 265 million US dollars.

The issue is how effectively the emergency stocks could mitigate welfare deterioration. MAFF (2001) reports that the annual storage costs of the emergency stocks in Japan reach 150 million US dollars. When we regard only improvements in the mean of EV as the social benefit of the emergency stocks—omitting capital gains and losses from the release of stocks—the emergency stocks would not seem worth maintaining for risk-neutral or moderately risk-averse people. This result suggests that we should reduce the amount of emergency stocks or should keep them somewhere abroad, where cheaper storage costs are offered. For example, annual storage costs are estimated to be 22.5 US dollars per paddy rice ton in Thailand by the International Crop Reserve Research Workshop (2001). In this case, the annual storage costs would amount to 34 million US dollars. Although we would have to bear the risk of transportation problems between the distant warehouses and Japan, the expected benefits of the rice stock stored abroad could be larger than the storage costs.

4.6 Impact of Export Quotas

If we consider the full inter-sectoral reallocation of factors induced by the rice trade liberalization by Japan, we find more drastic contraction of the domestic paddy rice sector in Japan, as the intermediate equilibrium suggests (Table 9). The results indicate that the domestic production of paddy rice would become almost nil. Land, which is the sector-specific factor for the agricultural sectors, would be reallocated from the paddy rice sector to the other two agricultural sectors, while its price would fall significantly, mainly due to the contraction of the paddy rice sector.

After computing the intermediate equilibrium, we assume the immobility of capital and land among sectors in simulations of productivity shocks alone (Scenario M) and those with export quotas (Scenario Q). As the reallocation of all the factors in the above-mentioned intermediate situation would intensify the welfare improvements by the rice trade liberalization, the mean of the welfare impact would be found larger in Scenario M (14,347 million US dollars) (upper panel of Table 10) than that in Scenario A1 (6,707 million US dollars) (Table 8). (Note that the only difference in assumption between Scenarios A1 and M is the inter-sectoral mobility of capital and land.)

Simulating the concerns of protectionists, we assume export quotas by the four major rice exporters to Japan. When they limit the volume of paddy rice exports to as low as the original MA level, Japan would be severely affected. While the gains from trade have been found remarkable in the previous simulations, Japan would suffer far larger welfare deterioration in this scenario (lower panel of Table 10). Moreover, Japan's calorie intake would become significantly lower than the emergency level defined by the MAFF. As indicated in Figure 16, Japan's calorie intake would be comparable to that in extremely poor African countries like Eritrea, Congo, and Burundi in 2001–2003.[12] No amount of emergency stock that Japan could realistically hold would cover such a huge loss of food.

We should consider two points in interpreting these results. One is that while we conducted a Monte Carlo simulation with respect to the productivity shock, we introduced the export quotas in a deterministic manner. That is, the welfare impact of Scenario Q suggests only conditional welfare impact given the imposition of export quotas. In this case, depending on the assumption about the probability that export quotas are set by the four countries, our overall evaluation would differ. If we expect such an emergency situation to take place frequently, such as once in ten years, the overall net benefit of the rice trade liberalization would be negative. In contrast, if the emergency situation were to happen as seldom as once in 100 years, we may well interpret the adverse impact of the export quota as being not so large considering gains attained in usual situations.

Historically speaking, Japan has experienced an effective embargo only once, during World War II. Another brief embargo-like situation occurred in 1973, when the US halved its soybean exports for two months. Recently, while some net rice importers or marginal exporters like the Philippines, China, and Indonesia have banned or restricted rice

[12] Source: FAOSTAT.

exports in 2008, Thailand, a large net rice exporter, stated it would never restrict rice exports. Cambodia, another net rice exporter, had set a ban on its rice exports for two months but resumed exporting in May 2008. In addition, the US and Australia—the major rice exporters for Japan—have not taken any special measures for rice in reaction to the recent commodity price boom. It should be noted that three out of these four major rice exporters to Japan have not set any rice export restrictions after the end of World War II.

The second point to consider in interpreting the results is that while Japan's rice trade liberalization and the resulting contraction of its domestic production indicate its commitment to foreign supply sources, these counterpart countries are also supposed to commit their exports to Japan. Comparing the welfare impact in Scenarios M and Q, we find that the US and Australia would suffer from their own export quotas while China and Thailand would slightly gain. For those two countries that would stand to lose from imposing export quotas, it would be unreasonable to impose such quotas. Although we can only guess about the probability of their imposing export quotas, the probability would not be expected to be high considering the increasing mutual interdependence in the recent world economy.

5. Concluding Remarks

To analyze the impact of factors that can secure or endanger Japan's national food security, we developed a stochastic world trade computable general equilibrium (CGE) model and carried out Monte Carlo simulations. The major findings of our analysis are as follows. (1) If rice productivity shocks are anticipated abroad, there is no statistically significant chance for the Japanese economy to be worse off under free rice trade even though fluctuations of the country's welfare would increase due to foreign-made productivity shocks. (2) If productivity shocks are anticipated in the domestic rice sector in Japan, rice trade liberalization would not only increase the mean of welfare, but would also decrease its volatility. Combining these two findings, we can conclude that protection of the domestic rice market harms rather than ensures Japan's national food security. (3) The current policy to secure the rice supply with emergency stocks is not effective in the sense that the expected gains achieved by the emergency stocks are obviously less than the annual costs for storing these stocks. This implies that the optimal size of the emergency stock should be much less than the current size and that the emergency stock should be kept in some other countries that offer cheaper storage costs. (4) If export quotas were set by the four major rice exporters to Japan, Japan would considerably suffer. However, two of them would also suffer from their own quota imposition, so they would be little likely to impose such quotas. As long as this continues to be true, the overall benefits of rice trade liberalization would be positive for Japan.

Some reservations regarding our analysis should be considered. In our Monte Carlo simulations, we assumed that productivity shocks follow normal distribution. However, nature sometimes brings more disastrous crop failures than we expect. Households are often very sensitive to a slight shortfall of essential commodities like food but do not benefit much from a good harvest once they are satisfied with their level of food consumption, particularly in developed countries. We can verify our simulation results considering other distributions for productivity shocks and functional forms for the household utility function.

In addition to the official emergency stocks, there are rice inventories held by private agents like dealers. Such private inventories also contribute to mitigating shortfalls of the rice supply. We would have found the effectiveness of the official emergency stocks much smaller if we had considered these private stocks.

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[Tables and Figures for the Main Text]

Table 1: Rice Imports and their Trade Barriers in Japan

	Paddy Rice		Processed Rice	
Imports from:	Value [mil. USD]	Trade Barriers [%]	Value [mil. USD]	Trade Barriers [%]
China	1.0	1,000	43.9	1,135
India	0.4	0	1.5	829
Indonesia	0.0	0	1.5	0
Bangladesh	0.0	0	0.1	929
Vietnam	0.2	0	3.7	929
Thailand	0.0	0	27.8	1,186
Philippines	0.0	0	1.4	0
US	33.2	804	65.0	929
Australia	7.4	804	28.0	927
Rest of Asia	1.0	581	4.2	453
Other Countries	2.4	30	6.1	274
Total	45.6		183.2	

Note: Trade barriers consist of tariff and tariff-equivalent non-tariff barriers.
Source: GTAP database version 6.

Table 2: Paddy Rice Production by Country in 2001

Country	Production [1,000 tons]	Share [%]
China	179,305	30.0
India	139,900	23.4
Indonesia	50,461	8.4
Bangladesh	36,269	6.1
Vietnam	32,108	5.4
Thailand	26,523	4.4
Myanmar	21,916	3.7
Philippines	12,955	2.2
Japan	11,320	1.9
Brazil	10,184	1.7
Others	76,716	12.8
Total	597,657	100.0

Source: FAOSTAT

Table 3: List of Regions and Sectors in the Model

Region	Sector
Japan	Paddy Rice*
China	Wheat*
India	Other Agriculture*
Indonesia	Processed Rice*
Bangladesh	Other Food*
Vietnam	Manufacturing
Thailand	Services
Philippines	Transportation
US	
Australia	
Rest of Asia	
Other Countries	

Note: Asterisks indicate food commodities used for the food composite.

Table 4: Scenario Design

Scenario	Scenario Factors				
	Trade Libera-lization	Shocks in Japan	Shocks in ROW	Emergency Stocks of Rice	Export Quota
T0	-	-	-	-	-
T1	x	-	-	-	-
R0	-	-	x	-	-
R1	x	-	x	-	-
J0	-	x	-	-	-
J1	x	x	-	-	-
A0	-	x	x	-	-
A1	x	x	x	-	-
S	-	x	x	x	-
M	x	x	x	-	-
Q	x	x	x	-	x

Table 5: Regression Results of Paddy Rice Productivity
[Dependent variable: rice productivity index (2001=1.00)]

	Regression Results of Paddy Rice Productivity				Summary Statistics of the Monte Carlo Draws	
	Intercept	Time Trend	S.D. of Residuals	R^2	Min.	Max.
Japan	–9.7352 (–1.02)	0.0053 (1.12)	0.0801	0.088	0.75	1.31
China	–12.9460 (–4.16)**	0.0070 (4.47)**	0.0261	0.606	0.91	1.08
India	–15.6576 (–3.1)**	0.0083 (3.28)**	0.0423	0.453	0.87	1.16
Indonesia	–4.2802 (–1.93)*	0.0026 (2.38)**	0.0186	0.304	0.94	1.07
Bangladesh	–47.7156 (–8.57)**	0.0243 (8.73)**	0.0467	0.854	0.84	1.13
Vietnam	–54.6946 (–28.85)**	0.0278 (29.33)**	0.0159	0.985	0.95	1.05
Thailand	–35.8382 (–10.17)**	0.0184 (10.43)**	0.0295	0.893	0.89	1.10
Philippines	–22.8654 (–3.82)**	0.0119 (3.97)**	0.0502	0.548	0.83	1.16
US	–26.4873 (–6.07)**	0.0137 (6.28)**	0.0366	0.752	0.86	1.11
Australia	–5.9156 (–0.56)	0.0034 (0.65)	0.0885	0.031	0.74	1.25
Rest of Asia	–19.6074 (–7.76)**	0.0103 (8.14)**	0.0212	0.836	0.94	1.07
Other Countries	–33.3938 (–12.26)**	0.0172 (12.6)**	0.0228	0.924	0.93	1.08

Note: T-values are in parentheses. *, **, and *** indicate parameters are significant at 10%, 5%, and 1% significance levels.
Means and standard deviations of the Monte Carlo draws are all consistent with those of the original estimates for the residuals.

Table 6: Simulation Results of Scenario T1 for Japan

	Changes in Quantity [%]			
	Output	Consumption	Imports	Exports
Paddy Rice	–48.7	9.5	1,545.8	111.6
Wheat	0.5	2.8	2.8	–2.4
Other Agriculture	0.8	2.7	3.8	–2.4
Processed Rice	–36.8	10.2	1,217.4	85.8
Other Food	2.4	2.9	1.2	1.9
Manufacturing	0.4	–0.3	–0.8	1.1
Services	–0.0	–0.1	–0.7	0.7
Transportation	–0.1	–0.1	–0.8	0.6
	Changes in Price [%]			
	Output	Consumption	Imports	Exports
Paddy Rice	–37.3	–46.2	–71.6	–17.0
Wheat	1.9	1.5	1.3	1.2
Other Agriculture	2.8	2.6	1.4	1.3
Processed Rice	–37.8	–49.5	–80.7	–5.9
Other Food	0.4	0.5	0.9	0.2
Manufacturing	0.1	0.1	0.4	0.3
Services	–0.0	–0.0	0.3	0.3
Transportation	–0.0	–0.0	0.3	0.4

Note: Changes from the Base (Scenario T0).

Table 7: Welfare Impact of Rice Trade Liberalization in Scenario T1

	EV [mil. USD]	EV/GDP [%]
Japan	6,749	0.17
China	–345	-0.03
India	13	0.00
Indonesia	–43	-0.03
Bangladesh	–2	0.00
Vietnam	62	0.19
Thailand	253	0.22
Philippines	–8	-0.01
US	1,926	0.02
Australia	125	0.04
Rest of Asia	280	0.02
Other Countries	–656	-0.01
Total	8,354	

Table 8: Simulation Scenarios and Summary Statistics of Simulation Results

Scenario	Scenario Factors: Trade Libera-lization	Shocks in Japan	Shocks in ROW	Emergency Stocks of Rice	Simulation Results for Japan: Welfare Mean [mil. USD]	Welfare S.D.	Mean of Self-sufficiency Rate of Rice [%]
T0	-	-	-	-	0	0	94.0
T1	x	-	-	-	6,749	0	73.4
R0	-	-	x	-	1	25	94.0
R1	x	-	x	-	6,750	95	73.6
J0	-	x	-	-	–192	1168	93.7
J1	x	x	-	-	6,707	402	73.0
A0	-	x	x	-	–191	1169	93.7
A1	x	x	x	-	6,707	416	73.3
S	-	x	x	x	–83	1009	91.8

Note: Distribution of Japan's EV for each scenario is also shown in Figures 6, 9, 10, and 14.

Table 9: Simulation Results for the Intermediate Equilibrium for Japan

Changes in Quantity [%]	Output	Consumption	Imports	Factor: Capital	Factor: Labor	Factor: Land
Paddy Rice	–97.2	16.3	5012.9	–97.3	–97.3	–96.6
Wheat	46.3	5.5	–5.0	42.2	42.2	79.0
Other Agriculture	5.8	5.9	–6.6	3.8	3.8	30.6
Processed Rice	–43.4	13.0	1607.4	–43.4	–43.4	–
Other Food	5.3	5.5	–0.7	5.3	5.2	–
Manufacturing	0.7	–0.1	–0.8	0.7	0.6	–
Services	0.0	–0.1	–0.5	0.1	0.0	–
Transportation	–0.1	–0.2	–0.5	–0.0	–0.1	–

Changes in Price [%]	Output	Consumption	Imports	Factor: Capital	Factor: Labor	Factor: Land
Paddy Rice	–9.7	–62.7	–84.6	–0.1	–	–68.3
Wheat	–8.1	–1.1	1.3	–0.1	–	–68.3
Other Agriculture	–5.9	–5.0	–0.3	–0.1	–	–68.3
Processed Rice	–35.8	–50.4	–82.7	–0.1	–	–68.3
Other Food	–1.8	–1.5	0.6	–0.1	–	–68.3
Manufacturing	–0.1	–0.1	0.2	–0.1	–	–68.3
Services	–0.1	–0.1	0.2	–0.1	–	–68.3
Transportation	–0.1	–0.1	0.2	–0.1	–	–68.3

Note: Labor is chosen as a numeraire, so its price shows no change.

Table 10: Welfare Impact in Scenarios M and Q

Scenario M	EV [mil. USD]			EV/GDP
	Min.	Average	Max.	[%]
Japan	13,004	14,347	15,163	0.35
China	–2,391	77	1,358	0.01
India	–1,908	–71	937	–0.02
Indonesia	–497	–33	372	–0.02
Bangladesh	–1,291	–43	504	–0.09
Vietnam	–121	37	178	0.11
Thailand	–74	179	395	0.16
Philippines	–1,043	–41	361	–0.06
US	1,031	2,000	3,027	0.02
Australia	–2	156	381	0.05
Rest of Asia	–1,558	–511	482	–0.04
Other Countries	–1,747	–214	1,346	–0.00
Total		15,867		0.05

Scenario Q	EV [mil. USD]			EV/GDP
	Min.	Average	Max.	[%]
Japan	–105,645	–92,775	–80,122	–2.29
China	–2,041	353	1,623	0.03
India	–1,626	555	1,799	0.12
Indonesia	–532	–45	378	–0.03
Bangladesh	–1,343	–42	528	–0.09
Vietnam	1,012	1,377	1,740	4.21
Thailand	–236	21	252	0.02
Philippines	–1,209	–118	314	–0.16
US	–2,185	–1,549	–745	–0.02
Australia	–623	–579	–527	–0.17
Rest of Asia	2,901	4,699	6,460	0.38
Other Countries	–2,058	–540	975	–0.00
Total		–88,688		–0.29

Note: EV/GDP is computed for the average of EV.

Figure 1: Productivity Fluctuation of Paddy Rice
[unit: tons/hectare]

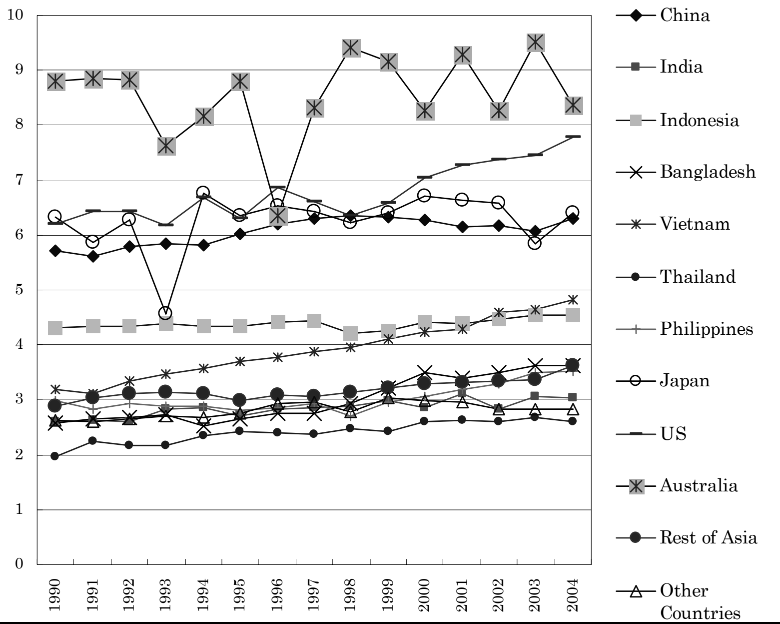
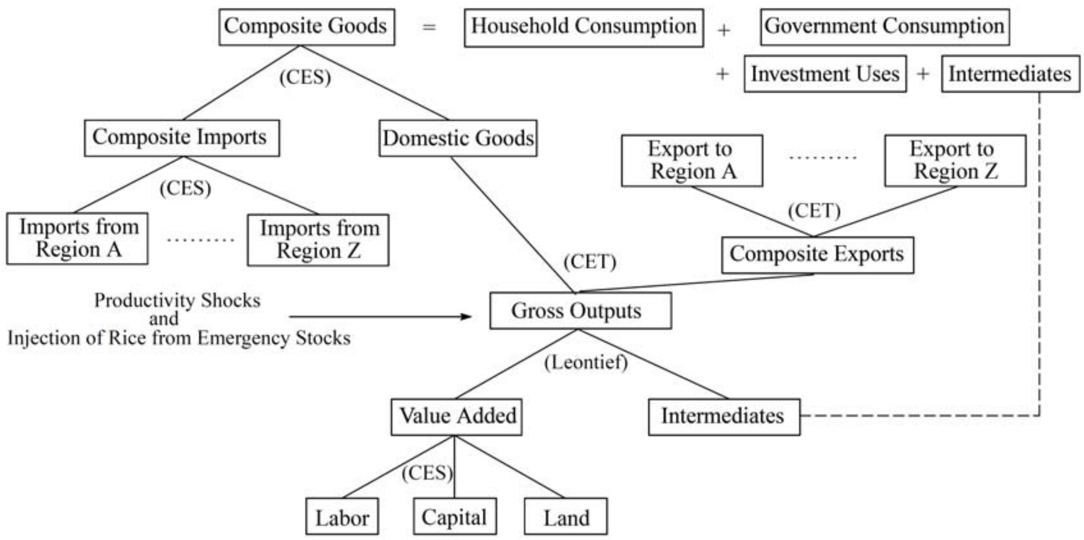
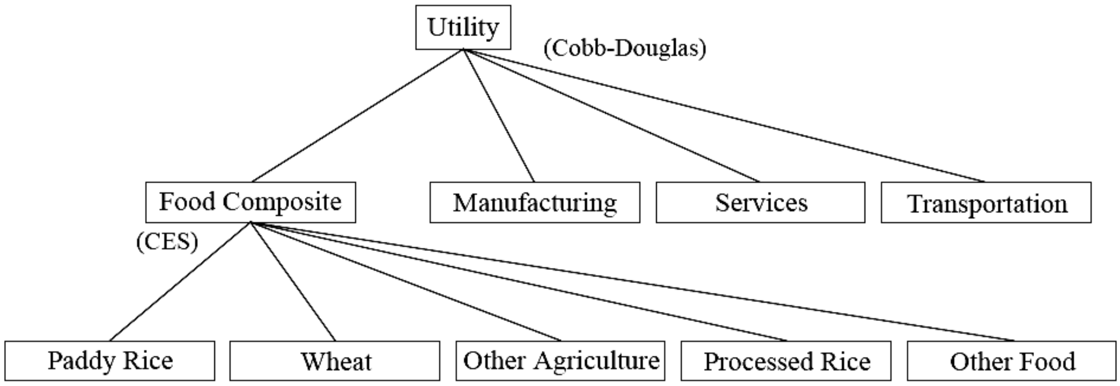


Figure 2: Model Structure



Note: CES/CET stands for constant elasticity of substitution/transformation.

Figure 3: Household Consumption



Note: CES stands for constant elasticity of substitution.

Figure 4: Impact of Productivity Shocks and Trade Liberalization on Distribution of Japan's Welfare

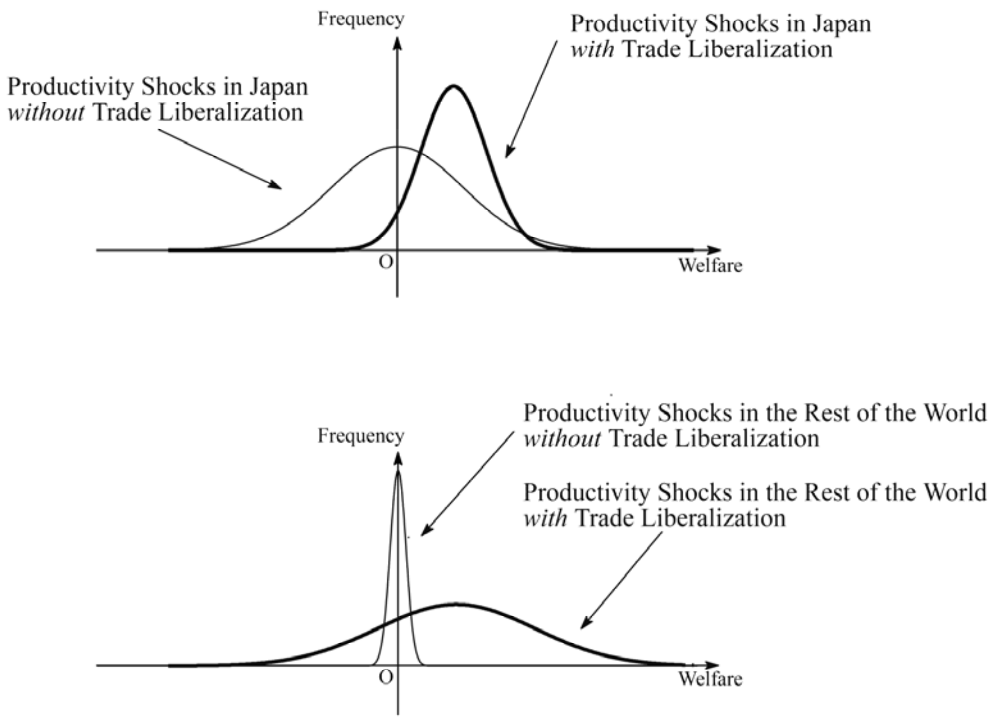


Figure 5: Distribution of Rice Supply Considering Emergency Stocks

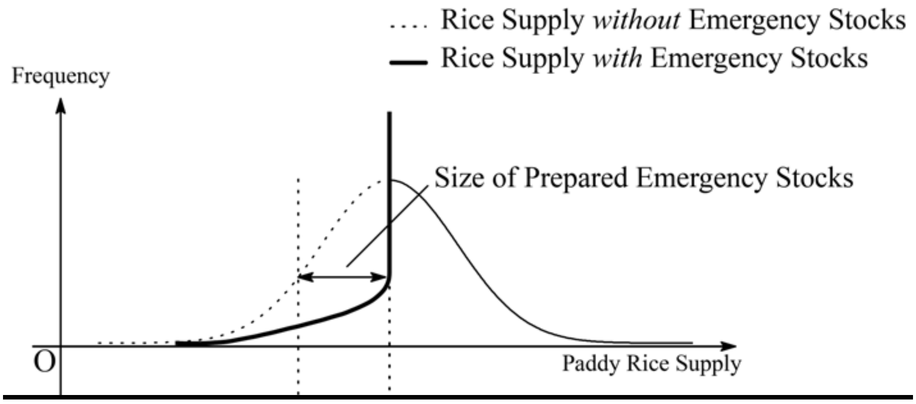


Figure 6: Timing of Factor Reallocation and Shocks

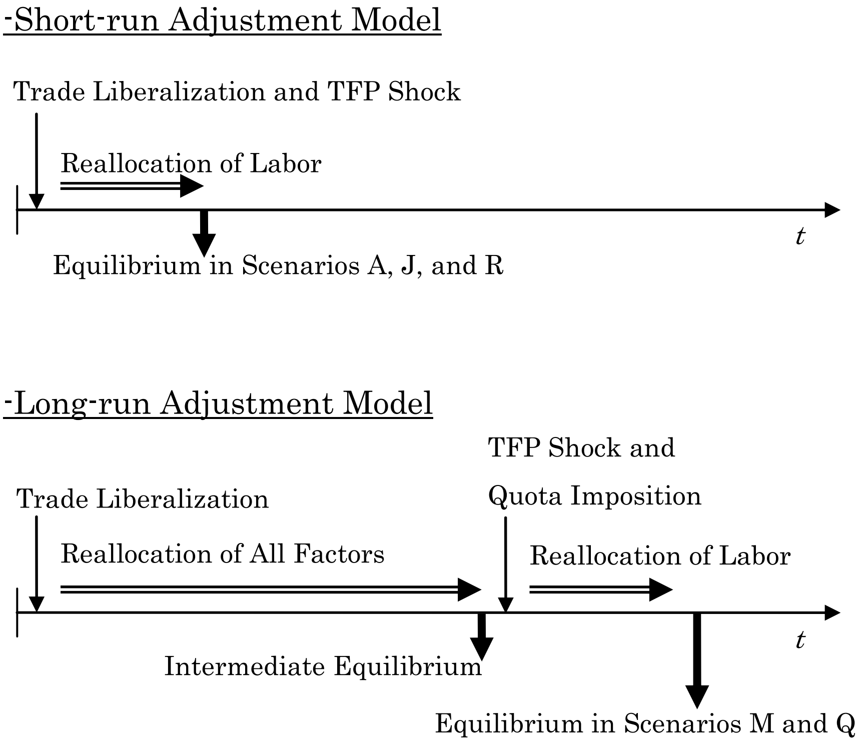


Figure 7: Impact of Foreign-made Shocks on Japan's Welfare
[unit: mil. USD]

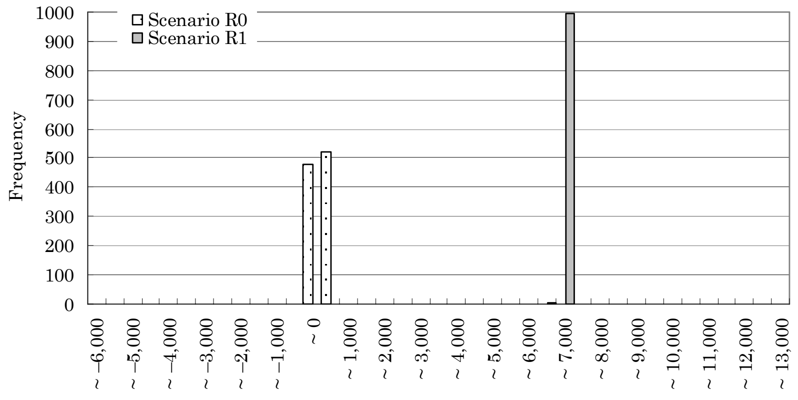
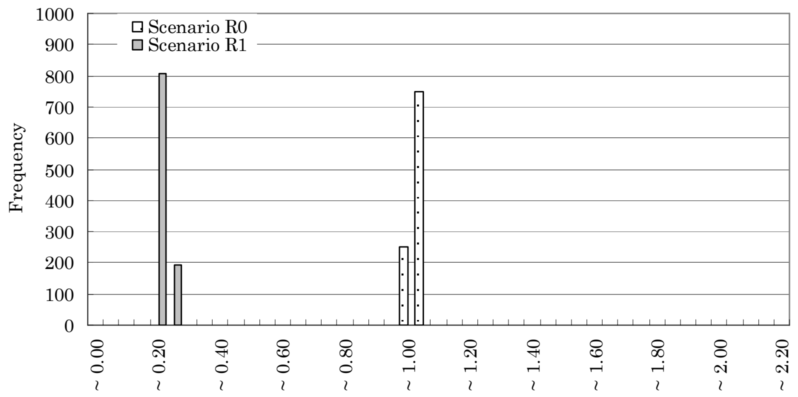


Figure 8: Impact of Foreign-made Productivity Shocks on the Import Price of Processed Rice for Japan
[unit: Price Index Calibrated to the Base Run Price (=1.00)]



Note: The import price refers to the price of composite imports shown in Figure 2.

Figure 9: Impact of Foreign-made Productivity Shocks on Household Processed Rice Consumption in Japan
[unit: Quantity Index Calibrated to the Base Run Values in mil. USD]

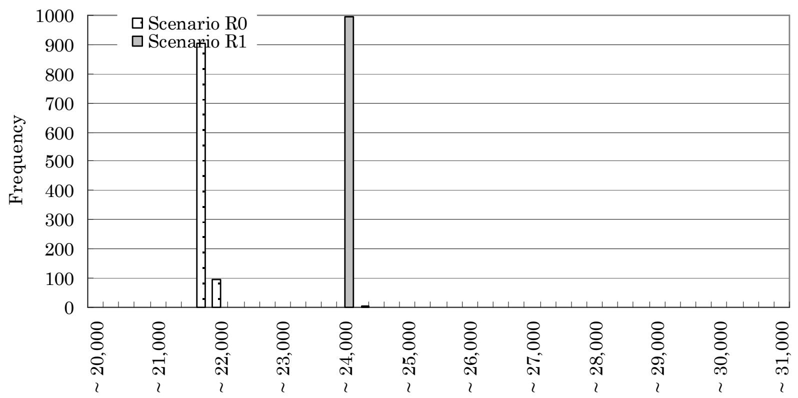


Figure 10: Impact of Domestic-made Shocks on Japan's Welfare
[unit: mil. USD]

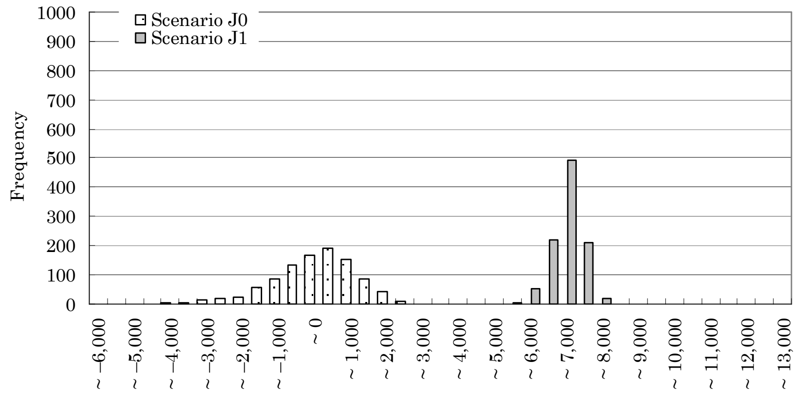


Figure 11: Overall Impact of Foreign- and Domestic-made Shocks on Japan's Welfare
[unit: mil. USD]

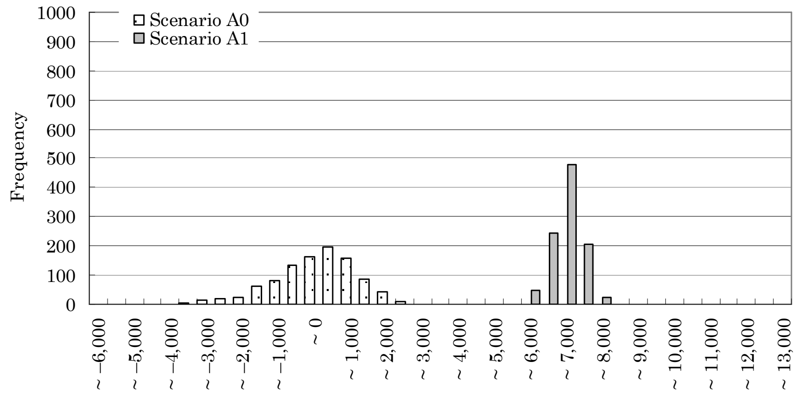


Figure 12: Overall Impact of Foreign- and Domestic-made Shocks on Japan's Calorie Intake
[unit: kcal/day/person]

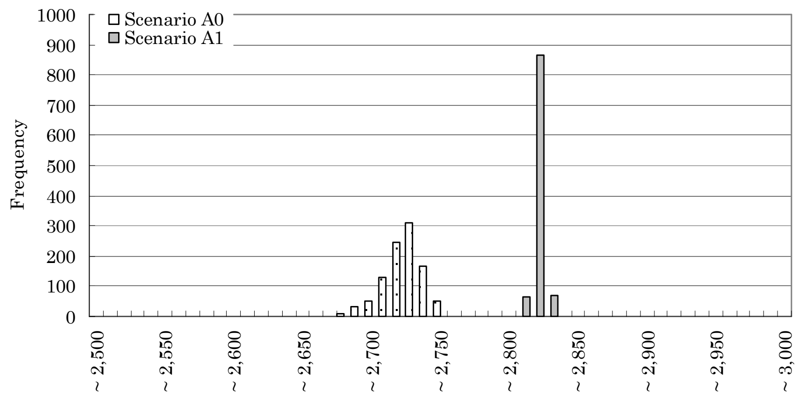


Figure 13: Effects of Emergency Stocks on the Domestic Processed Rice Price in Japan
[unit: Price Index Calibrated to the Base Run Price (=1.00)]

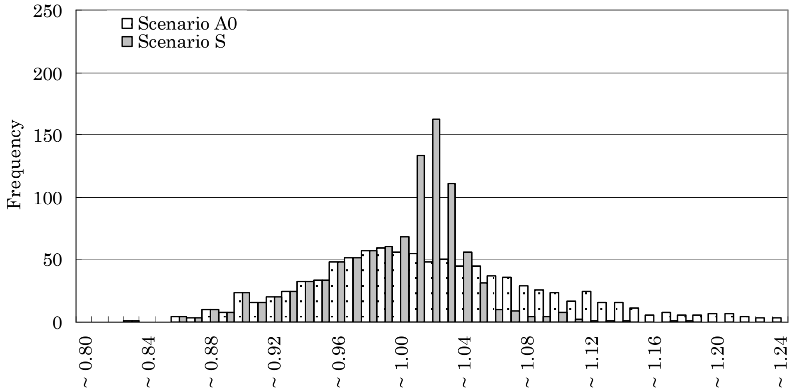


Figure 14: Effects of Emergency Stocks on the Domestic Processed Rice Consumption in Japan
[unit: Quantity Index Calibrated to the Base Run Value in mil. USD]

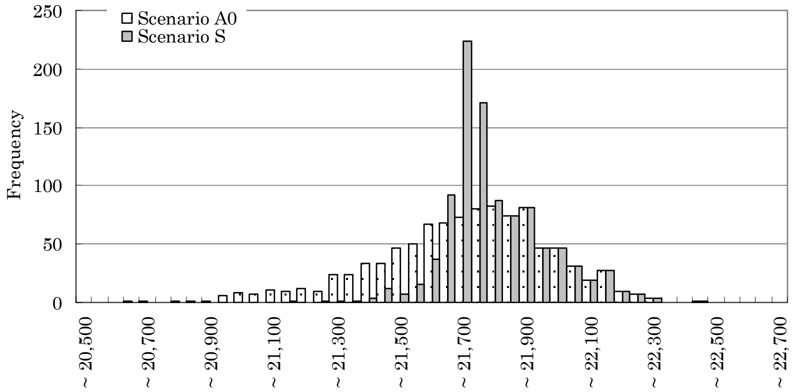


Figure 15: Effects of Emergency Stocks on Japan's Welfare
[unit: mil. USD]

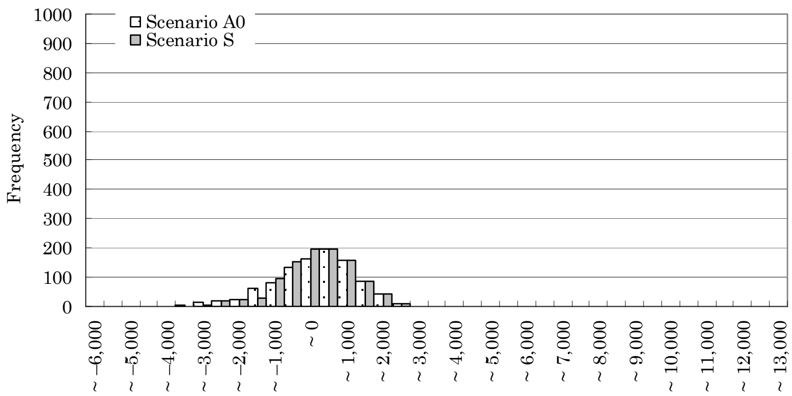
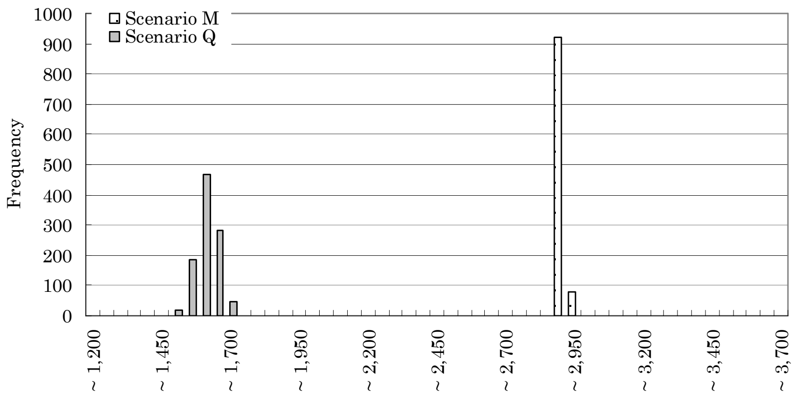


Figure 16: Effects of Export Quotas on Japan's Calorie Intake
[unit: kcal/day/person]



Appendix: Sensitivity Analysis

We have conducted sensitivity analyses with respect to four key parameters of our CGE model. They are shown as follow.

A.1 Sensitivity Analysis: Price Elasticity of Food Consumption

We use 0.1 for the elasticity of substitution ε^f in the food composite CES function, which is approximately equal to the price elasticity of food commodities. However, this elasticity might seem too small considering the fact that there are a variety of estimates for the price elasticity of rice demand in Japan (Table A.1). As the majority of recent estimates (except those by Chern *et al.* (2002)) suggest the elasticity would be smaller than unity but have never converged to any conclusive magnitude to date, we conduct a sensitivity analysis with respect to this elasticity. We alternatively assume 1.0 for ε^f and find that the increases of consumption would be much larger to mitigate the deterioration of domestic production of paddy rice to some extent (Table A.2). Imports of rice would be found in a larger magnitude. As food demand is assumed to be more price-elastic, price adjustments would be less intensified. Welfare impact would be about 40% larger than those in the original simulations (Table A.3).

Regarding the results of our Monte Carlo simulations, since larger elasticity makes the household consumption more sensitive to price falls from rice trade liberalization, volatility of EV would be found larger in free trade Scenarios R1, J1, and A1 (Table A.4). As Figures A.1–A.4 show, distributions with and without trade liberalization in Scenarios R0, R1, J0, J1, A0, and A1 would be also consistently separated from each other with this alternative assumption about the elasticity. Figure A.5 also suggests the robustness of our finding about the ineffectiveness of the emergency rice stocks demonstrated in Scenario S. The means of self-sufficiency rates under free rice trade in Table A.4 would be found about two percentage points lower than those in Table 8. In sum, all of our findings are qualitatively robust irrespective of the assumptions about the elasticity of substitution in the food composite CES function.

Table A.1: Estimates of Price Elasticity of Rice Demand

	Estimates of price elasticity	Type of rice[/1]	Sample period	Type of sample	Data source[/2]
Otsuka (1984)	0.094 – 0.127	Rice	1955–80	annual	FIES; Farming Household Survey
Sawada (1984)	0.2153 – 0.4091 1.4161 – 2.7977	GMR PMR	1963–79	annual	FIES
Sawada (1985)	1.07 1.21	PMR	1972–75 1976–82	pooled	FIES
Kobayashi (1988)	0.28	GMR	1968–84	annual	FIES
	0.184 0.103	Rice	1968–84 1974–84	annual	Food Demand and Supply
Kusakari (1991)	0.469 1.104 0.919	PMR GMR Category 1, 2 GSPR	1981–88	monthly	Rice and Crop Consumption Survey; Annual Report of Rice and Crops Market Price
Hasebe (1996)	1.811 0.365	PMR GSPR	1969–73, 77–86	annual	FIES
Kako *et al.* (1997)	0.13	Rice	1970–91	annual	FIES
Chino *et al.* (2000)	0.3315	Rice	1970–1994	annual	FIES
Chern (2001)	0.140	Rice	1986–95	pooled	FIES
Chern *et al.* (2002)	1.824 1.551 – 1.906	Rice (all sample) Rice (by 5 income groups)	1997	cross-section	FIES

Note: Only estimates statistically significant at conventional significance levels and with the appropriate sign are shown here.

/1 GMR: government-marketed rice, PMR: privately marketed rice, and GSPR: government standard price rice.

/2 FIES: Family Income and Expenditure Survey by the Statistical Bureau, Ministry of Internal Affairs and Communications, Government of Japan.

Table A.2: Simulation Results of Scenario T1 for Japan (ε^f =1.0)

	Changes in Quantity [%]		
	Output	Consumption	Imports
Paddy Rice	–29.9	70.6	1,924.0
Wheat	0.4	–1.4	0.4
Other Agriculture	0.0	–0.2	–1.1
Processed Rice	–8.9	73.1	1,847.4
Other Food	0.5	0.3	–1.7
Manufacturing	0.5	–0.3	–1.1
Services	–0.0	–0.1	–0.9
Transportation	0.0	–0.2	–0.8
	Changes in Price [%]		
	Output	Consumption	Imports
Paddy Rice	–33.8	–41.5	–68.3
Wheat	1.2	1.3	1.3
Other Agriculture	–0.1	0.0	0.4
Processed Rice	–28.9	–42.3	–78.1
Other Food	–0.5	–0.4	0.4
Manufacturing	0.2	0.2	0.5
Services	–0.0	–0.0	0.4
Transportation	0.0	0.0	0.4

Table A.3: Simulation Results of Scenario T1 for Welfare (ε^f =1.0)

	EV [mil. USD]	EV/GDP [%]
Japan	9,519	0.24
China	–355	–0.03
India	15	0.00
Indonesia	–39	–0.03
Bangladesh	–2	–0.00
Vietnam	83	0.25
Thailand	394	0.34
Philippines	–18	–0.03
US	2,390	0.02
Australia	168	0.05
Rest of Asia	302	0.02
Other Countries	–697	–0.01
Total	11,758	

Table A.4: Summary Statistics of Simulation Results (ε^f =1.0)

Scenario	Simulation Results for Japan		
	Welfare		Mean of Self-sufficiency Rate of Rice
	Mean [mil. USD]	Variance	[%]
T0	0	0	94.0
T1	9,519	0	71.9
R0	–1	20	94.0
R1	9,518	109	71.9
J0	–156	1131	93.9
J1	9,460	581	71.5
A0	–157	1131	93.9
A1	9,458	593	71.6
S	–68	1006	91.7

Figure A.1: Impact of Foreign-made Shocks on Japan's Welfare (ε^f =1.0) [unit: mil. USD]

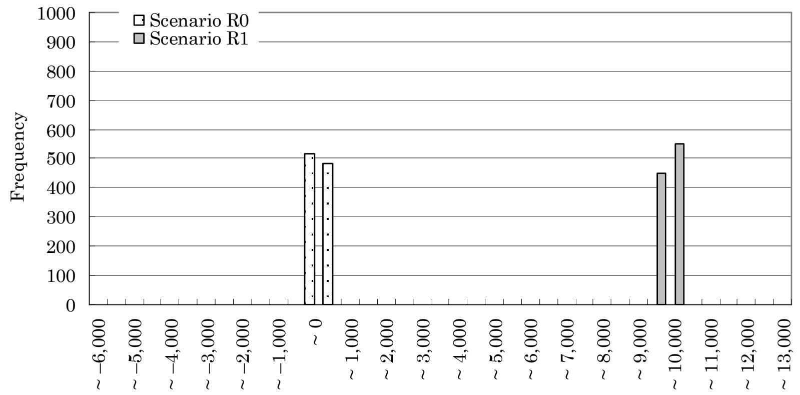


Figure A.2: Impact of Domestic-made Shocks on Japan's Welfare (ε^f =1.0) [unit: mil. USD]

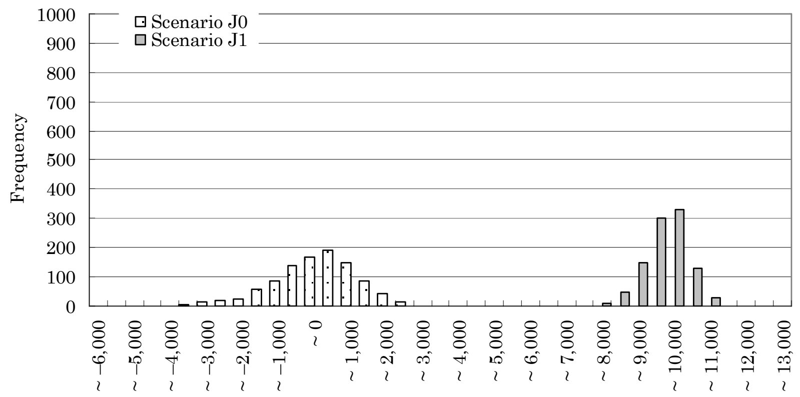


Figure A.3: Overall Impact of Foreign- and Domestic-made Shocks on Japan's Welfare (ε^f =1.0)
[unit: mil. USD]

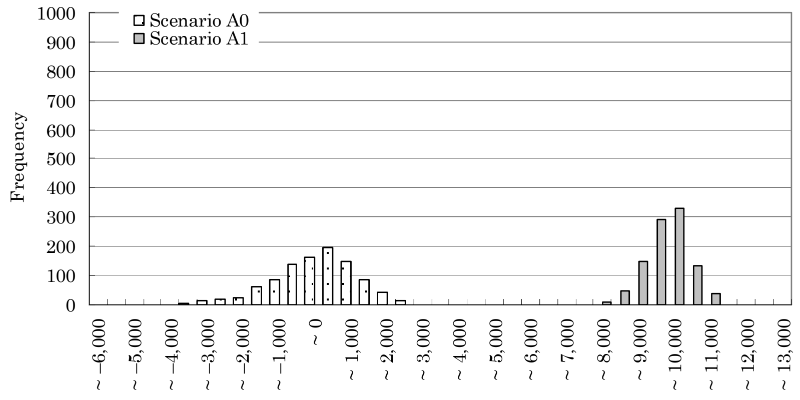


Figure A.4: Overall Impact of Foreign- and Domestic-made Shocks on Japan's Calorie Intake (ε^f =1.0)
[unit: kcal/day/person]

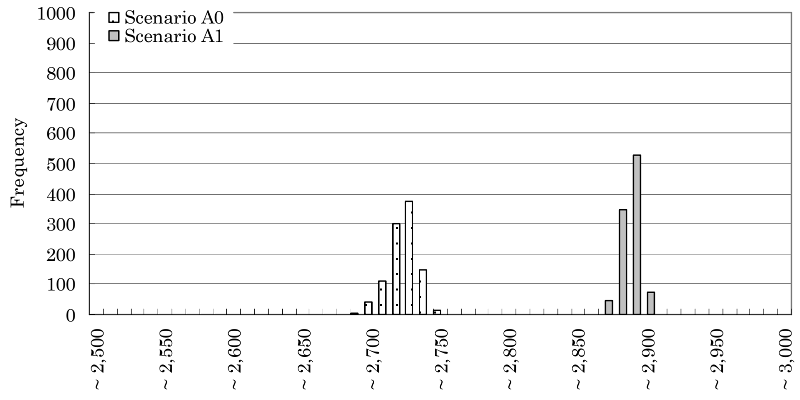
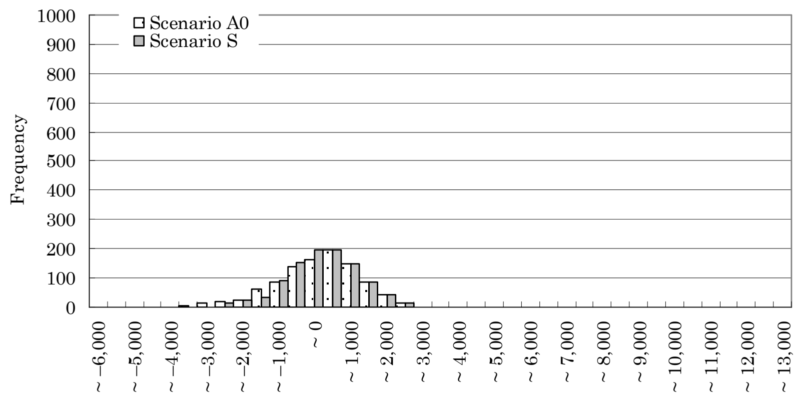


Figure A.5: Effects of Emergency Stocks for Japan's Welfare (ε^f =1.0)
[unit: mil. USD]



A.2 Sensitivity Analysis: Volatility of Productivity

There is some uncertainty in our estimates of productivity shocks shown in Table 5. We conduct a sensitivity analysis with twice as large standard deviations as those used in the main text. The simulation results suggest that the standard deviation of welfare in Table A.5 would become about twice as large as the original one in Table 8. The tails of welfare distributions would become longer to make the two distributions of welfare (and calorie intake) with and without rice trade liberalization closer to each other (Figures A.6–A.10).

This doubled standard deviation case still qualitatively supports our findings drawn from six simulations with Scenarios R0, R1, J0, J1, A0, and A1, except for the point that the two welfare distributions with and without trade liberalization slightly overlap with each other in Figures A.7 and A.8. The means of welfare under free rice trade would be marginally changed while those with rice trade protection would be increased to some extent since the larger volatility would exacerbate the slight welfare declines originating from the concavity of the utility function. Comparing the results of Scenarios A0 and S, the benefits of the emergency stocks would be 265 million US dollars, which is about 2.5 times as much as that expected in the original simulations. In this case, this benefit can cover the annual storage costs.

Table A.5: Summary Statistics of Simulation Results (with doubled σ_r)

Scenario	Welfare		Mean of Self-sufficiency Rate of Rice
	Mean [mil. USD]	S.D.	[%]
T0	0	0	94.0
T1	6,749	0	73.4
R0	5	51	94.1
R1	6,756	189	73.9
J0	–713	2773	93.1
J1	6,613	844	72.3
A0	–710	2777	93.2
A1	6,619	871	72.8
S	–445	2365	90.4

Figure A.6: Impact of Foreign-made Shocks on Japan's Welfare (with doubled σ_r)
[unit: mil. USD]

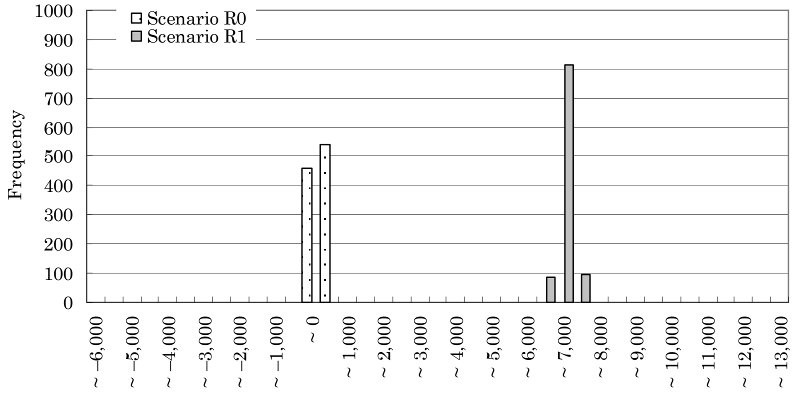


Figure A.7: Impact of Domestic-made Shocks on Japan's Welfare (with doubled σ_r)
[unit: mil. USD]

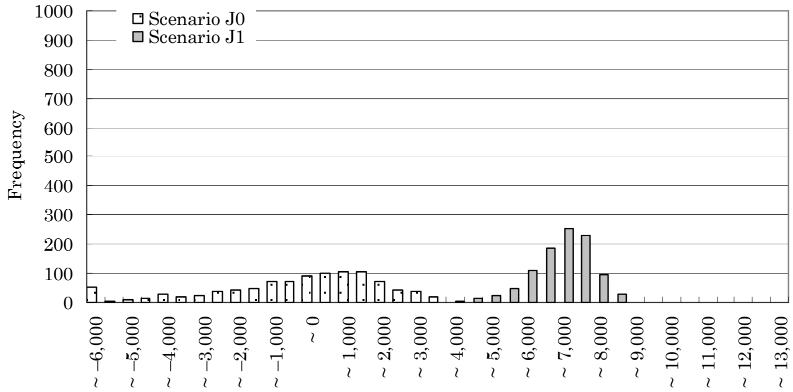


Figure A.8: Overall Impact of Foreign- and Domestic-made Shocks on Japan's Welfare (with doubled σ_r)
[unit: kcal/day/person]

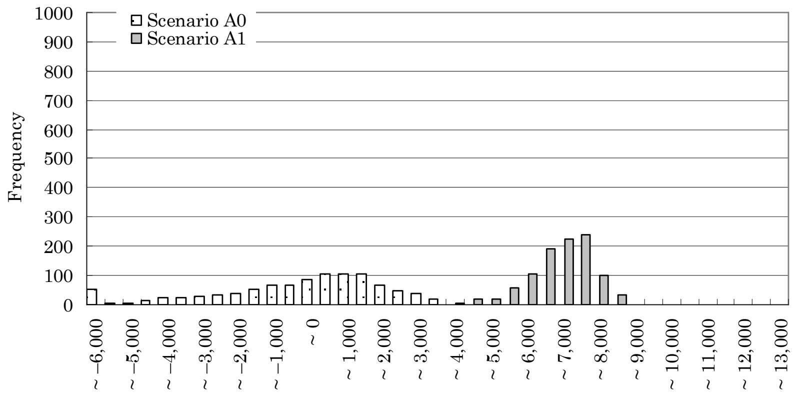


Figure A.9: Overall Impact of Foreign- and Domestic-made Shocks on Japan's Calorie Intake (with doubled σ_r)
[unit: kcal/day/person]

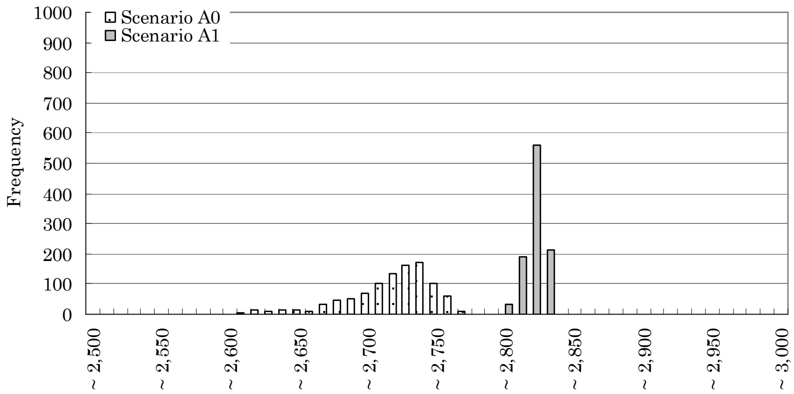
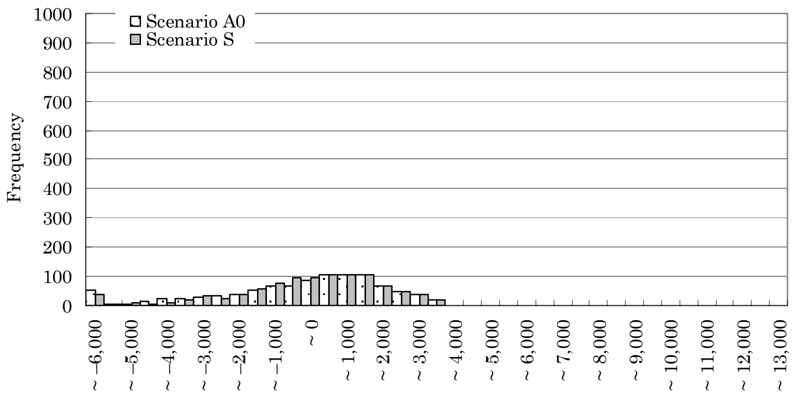


Figure A.10: Effects of Emergency Stocks for Japan's Welfare (with doubled σ_r)
[unit: mil. USD]



A.3 Sensitivity Analysis: Armington Elasticity

Elasticity of substitution for the Armington aggregation $1/(1-\eta_i)$ and elasticity of transformation for gross output $1/(\phi_i - 1)$ are obtained from the GTAP database version 6 (Table A.6). Their elasticity is doubled for the elasticity for import variety aggregation $1/(1-\varpi_i)$ and that for export variety production $1/(\varphi_i - 1)$. We carry out sensitivity analysis of our simulation results with respect to the Armington elasticity of substitution for the paddy rice and the processed rice sectors in Japan. We alternatively assume 30% larger and smaller elasticity for the paddy rice and the processed rice sectors. The results are reported in Figure A.11. In smaller elasticity cases, the deterministic gains from trade would become relatively smaller. Consequently, the two distributions of welfare with and without rice trade liberalization would get closer to overlap with each other only slightly in Scenarios J0, J1, A0, and A1. Our simulation results are in sum robust from a qualitative viewpoint.

Table A.6: Assumed Key Elasticity and its Alternative Values Used in Sensitivity Analysis

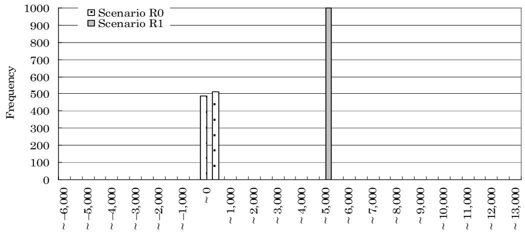
Sector	Elasticity of Substitution: Armington Composite	Elasticity of Substitution: Food Composite	Elasticity of Substitution: Value Added
Paddy Rice	5.05#	0.1	0.2*
Wheat	4.45	0.1	0.2*
Other Agriculture	2.23	0.1	0.2*
Processed Rice	2.60#	0.1	1.0
Other Food	2.48	0.1	1.0
Manufacturing	3.56	–	1.0
Services	1.94	–	1.0
Transportation	1.90	–	1.0
Sensitivity Analysis	**Alternative Elasticity**		
	+30%, –30% for the rice sectors (#)	1.0	0.1, 1.0 for the agricultural sectors (*)

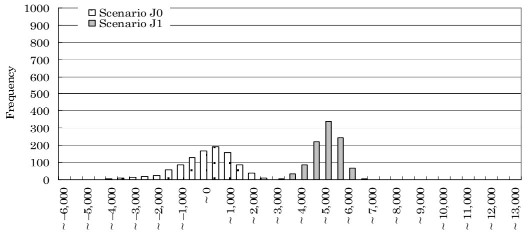
Figure A.11: Results of Sensitivity Analysis w.r.t. the Armington Elasticity

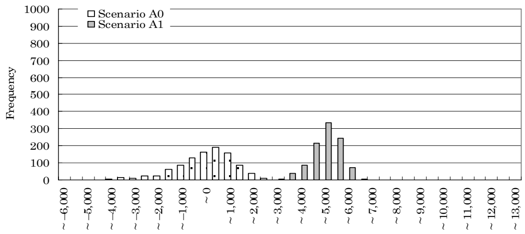
Panel a) Elasticity of substitution: –30 %

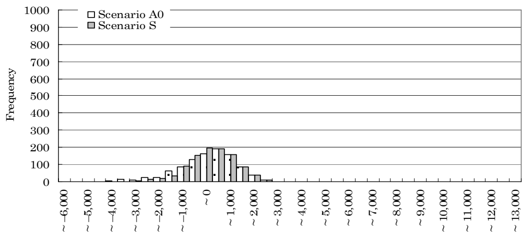
Scenario	Simulation Results: Indicators for Japan		
	Welfare		Mean of Self-sufficiency Rate of Rice [%]
	Mean [mil. USD]	S.D.	
T0	0	0	94.0
T1	4,768	0	83.6
R0	1	28	94.0
R1	4,769	53	83.8
J0	–213	1201	93.7
J1	4,692	605	83.4
A0	–212	1203	93.8
A1	4,693	609	83.6
S	–90	1016	91.7

Welfare [mil. USD]

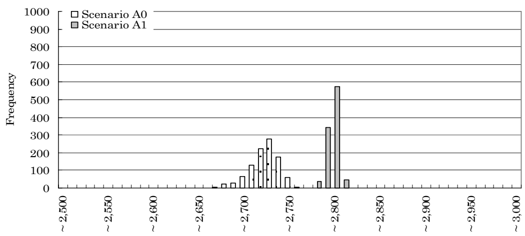








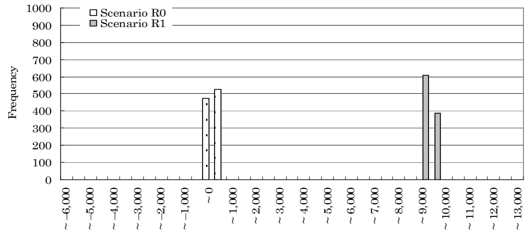
Calorie Intake [kcal/day/person]

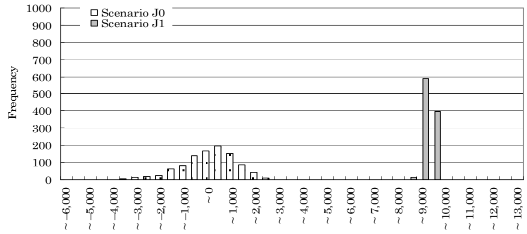


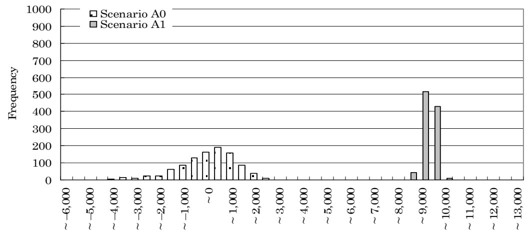
Panel b) Elasticity of substitution: +30 %

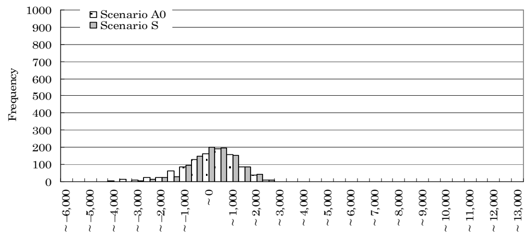
Scenario	Simulation Results: Indicators for Japan		
	Welfare		Mean of Self-sufficiency Rate of Rice [%]
	Mean [mil. USD]	S.D.	
T0	0	0	94.0
T1	8,962	0	58.7
R0	1	24	94.0
R1	8,965	162	59.2
J0	–176	1140	93.7
J1	8,949	191	58.3
A0	–212	1203	93.8
A1	8,952	256	58.7
S	–79	1001	91.9

Welfare [mil. USD]

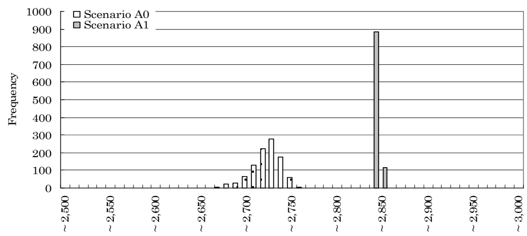








Calorie Intake [kcal/day/person]



A.4 Sensitivity Analysis: Value Added Aggregation

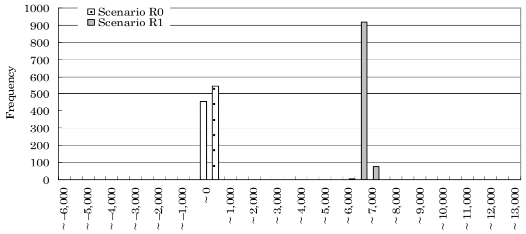
While we assume 0.2 for the elasticity of substitution between primary factors in the agricultural sectors (Table A.6), we alternatively assume 0.1 (panel a of Figure A.12) and 1.0 (panel b of Figure A.12) for the elasticity in this sensitivity analysis. The results indicate that the less elastic case implies smaller gains from trade and less deterioration of Japan's rice self-sufficiency rate. It should be noted that the two welfare distributions with and without trade liberalization never overlap with each other. The benefits of the emergency stocks would still fall short of the storage costs.

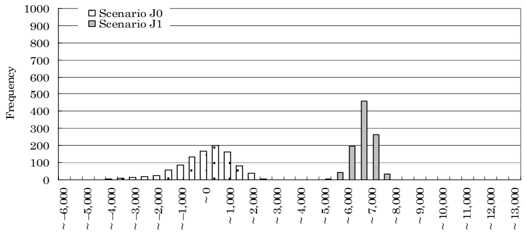
Figure A.12: Results of Sensitivity Analysis w.r.t. the elas. of sub. in Value Added

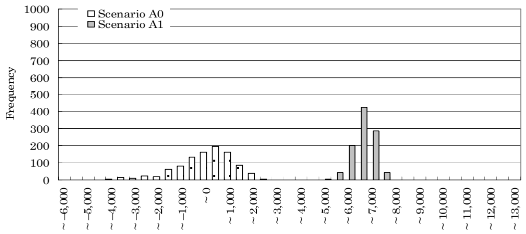
Panel a) Elasticity of substitution=0.1

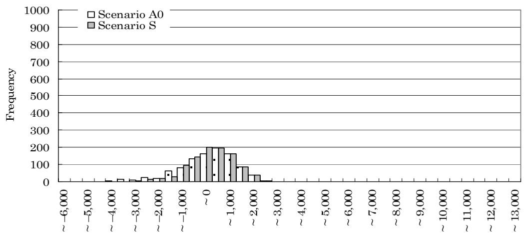
Scenario	Simulation Results: Indicators for Japan		
	Welfare		Mean of Self-sufficiency Rate of Rice
	Mean [mil. USD]	S.D.	[%]
T0	0	0	94.0
T1	6,319	0	75.5
R0	4	27	94.0
R1	6,323	122	75.7
J0	–218	1173	93.6
J1	6,272	424	75.2
A0	–215	1176	93.7
A1	6,277	444	75.4
S	–87	979	92.0

Welfare [mil. USD]

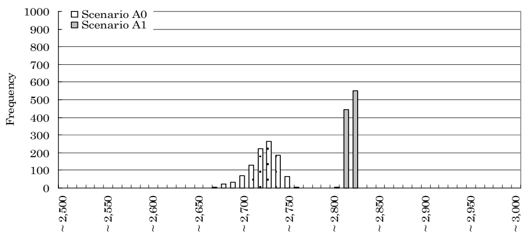








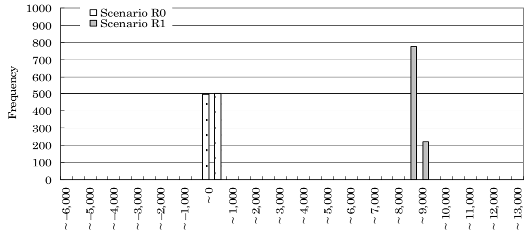
Calorie Intake [kcal/day/person]

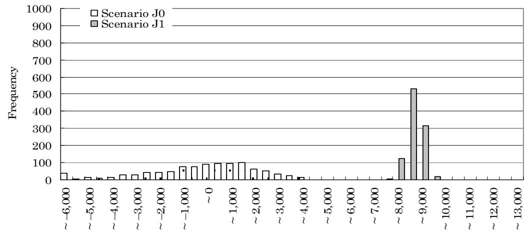


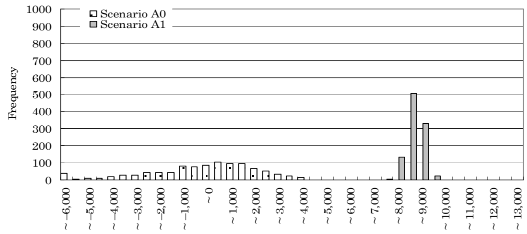
Panel b) Elasticity of substitution=1.0

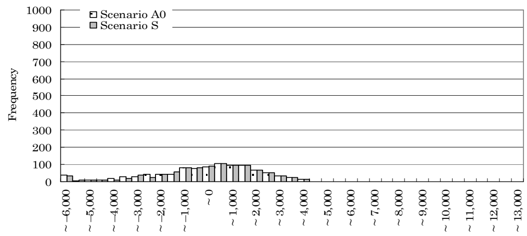
Scenario	Simulation Results: Indicators for Japan		
	Welfare		Mean of Self-sufficiency Rate of Rice
	Mean [mil. USD]	S.D.	[%]
T0	0	0	94.0
T1	8,389	0	60.6
R0	–0	39	94.0
R1	8,392	146	60.8
J0	–509	2499	93.6
J1	8,364	320	60.3
A0	–509	2499	93.7
A1	8,364	329	60.4
S	–403	2361	89.7

Welfare [mil. USD]

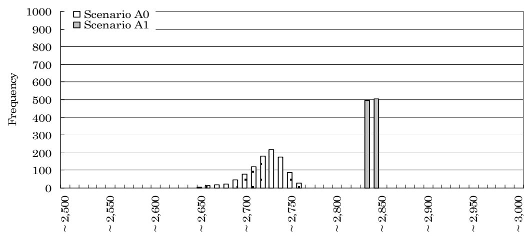








Calorie Intake [kcal/day/person]



Annex

B.1 Model Structure

The full description of our stochastic world trade computable general equilibrium model is as follows.

-Symbols

Sets

i, j : commodities/sectors (other than the food composite)

fd : food commodities/sectors

nfd : non-food commodities/sectors

ifd : non-food commodities plus the food composite

r, s, r' : regions

h : factors

Table B.1: List of Abbreviations of Regions and Sectors

Region	Abbreviation	Sector	Abbreviation
Japan	JPN	Paddy Rice	PDR
China	CHN	Wheat	WHT
India	IND	Other Agriculture	OTA
Indonesia	INS	Processed Rice	PCR
Bangladesh	BNG	Other Food	OTF
Vietnam	VTN	Manufacturing	MAN
Thailand	THL	Services	SRV
Philippines	PHL	Transportation	TRN
US	USA		
Australia	AUS		
Rest of Asia	ROA		
Other Countries	OTH		

Endogenous variables

$X^p_{i,r}$: household consumption

XFD_r : food composite

$X^g_{i,r}$: government consumption

$X^v_{i,r}$: investment uses

$X_{i,j,r}$: intermediate uses of the i-th good by the j-th sector

$F_{h,j,r}$: factor uses

$Y_{j,r}$: value added

$Z_{j,r}$: gross output
$Q_{i,r}$: Armington composite good
$M_{i,r}$: composite imports
$D_{i,r}$: domestic goods
$E_{i,r}$: composite exports
$T_{i,r,s}$: inter-regional transportation from the r-th region to the s-th region
TT_r: exports of inter-regional shipping service by the r-th region
Q^s: composite inter-regional shipping service

S_r^p: household savings
S_r^g: government savings
T_r^d: direct taxes
$T_{j,r}^z$: production taxes
$T_{j,s,r}^m$: import tariffs
$T_{j,r,s}^e$: export taxes

p_r^{XFD}: price of food composite
$p_{i,r}^q$: price of Armington composite goods
$p_{h,j,r}^f$: price of factors
$p_{j,r}^y$: price of value added
$p_{i,r}^z$: price of gross output
$p_{i,r}^m$: price of composite imports
$p_{i,r}^d$: price of domestic goods
$p_{i,r}^e$: price of composite exports
$p_{i,r,s}^t$: price of goods shipped from the r-th region to the s-th region
p^s: inter-regional shipping service price in US dollars
$\varepsilon_{r,s}$: exchange rates to convert the r-th region's currency into the s-th region's currency
EMS_r: release of emergency rice stocks

Exogenous variables and parameters
S_r^f: current account deficits in US dollars
$FF_{h,j,r}$: factor endowment initially employed in the j-th sector
$TFP_{j,r}$: productivity; $TFP_{PDR,r} \sim N(1, \sigma_r^2)$ or $N(1,0)$
σ_r: standard deviation of productivity in the paddy rice sector
$\overline{EMS}_r$: capacity of emergency rice stocks

$Z_{j,r}^{0}$: initial amount of gross output

τ_{r}^{d} : direct tax rates

$\tau_{i,r}^{z}$: production tax rates

$\tau_{i,s,r}^{m}$: import tariff rates on inbound shipping from the s-th region

$\tau_{i,r,s}^{e}$: export tax rates on outbound shipping to the s-th region

$\tau_{i,r,s}^{s}$: inter-regional shipping service requirement per unit transportation of the i-th good from the r-th region to the s-th region

-Household

(Utility function: $UU_r = XFD_r^{\alpha_r^{XFD}} \prod_{nfd} X_{nfd,r}^{p\ \alpha_{nfd,r}}$ $\forall r$)

Demand functions for consumption

$$X_{nfd,r}^{p} = \frac{\alpha_{nfd,r}}{p_{nfd,r}^{q}} \left(\sum_{h,j} p_{h,j,r}^{f} F_{h,j,r} - T_r^d - S_r^p \right) \qquad \forall nfd, r$$

$$XFD_r = \frac{\alpha_r^{XFD}}{p_r^{XFD}} \left(\sum_{h,j} p_{h,j,r}^{f} F_{h,j,r} - T_r^d - S_r^p \right) \qquad \forall r$$

Food composite aggregation function

$$XFD_r = \Theta_r \left(\sum_{fd} \Delta_{fd,r} X_{fd,r}^{p\ \Psi} \right)^{1/\Psi} \qquad \forall r$$

(Note that $\Psi = (\varepsilon^f - 1)/\varepsilon^f$.)

$$X_{fd,r}^{p} = \left(\frac{\Theta_r^{\ \Psi} \Delta_{fd,r} p_r^{XFD}}{p_{fd,r}^{q}} \right)^{\frac{1}{1-\Psi}} XFD_r \qquad \forall fd, r$$

Savings function

$$S_r^p = s_r^p \sum_{h,j} p_{h,j,r}^{f} F_{h,j,r} \qquad \forall r$$

-Value added producing firm

Factor demand function

$$F_{h,j,r} = \left(\frac{b_{j,r}^{\ \eta_j^{va}} \beta_{h,j,r} p_{j,r}^{y}}{p_{h,j,r}^{f}} \right)^{\frac{1}{1-\eta_j^{va}}} Y_{j,r} \qquad \forall h, j, r$$

Value added production function

$$Y_{j,r} = b_{j,r} \left(\sum_{h} \beta_{h,j,r} F_{h,j,r}^{\ \eta_j^{va}} \right)^{1/\eta_j^{va}} \qquad \forall j, r$$

-Gross output producing firm

(Production function: $Z_{j,r} = TFP_{j,r} \min\left(\left\{\frac{X_{i,j,r}}{ax_{i,j,r}}\right\}_i, \frac{Y_{j,r}}{ay_{j,r}}\right) \qquad \forall j,r$)

Demand function for intermediates

$$X_{i,j,r} = \frac{ax_{i,j,r} Z_{j,r}}{TFP_{j,r}} \qquad \forall i,j,r$$

Demand function for value added

$$Y_{j,r} = \frac{ay_{j,r} Z_{j,r}}{TFP_{j,r}} \qquad \forall j,r$$

Unit price function

$$p^z_{j,r} = \frac{1}{TFP_{j,r}}\left(\sum_i ax_{i,j,r} p^q_{i,r} + ay_{j,r} p^y_{j,r}\right) \qquad \forall j,r$$

-Government

Demand function for government consumption

$$X^g_{i,r} = \frac{\iota_{i,r}}{p^q_{i,r}}\left(T^d_r + \sum_j T^z_{j,r} + \sum_{j,s} T^m_{j,s,r} + \sum_{j,s} T^e_{j,r,s} - S^g_r\right) \quad \forall i,r$$

Direct tax revenue

$$T^d_r = \tau^d_r \sum_{h,j} p^f_{h,j,r} F_{h,j,r} \qquad \forall r$$

Production tax revenue

$$T^z_{j,r} = \tau^z_{j,r} p^z_{j,r} Z_{j,r} \qquad \forall j,r$$

Import tariff revenue

$$T^m_{j,s,r} = \tau^m_{j,s,r}\left[\left(1+\tau^e_{j,s,r}\right)\varepsilon_{s,r} p^t_{j,s,r} + \tau^s_{j,s,r}\varepsilon_{USA,r} p^s\right] T_{j,s,r} \qquad \forall j,s,r$$

Export tax revenue

$$T^e_{j,r,s} = \tau^e_{j,r,s} p^t_{j,r,s} T_{j,r,s} \qquad \forall j,r,s$$

Government savings function

$$S^g_r = s^g_r\left(T^d_r + \sum_j T^z_{j,r} + \sum_{j,s} T^m_{j,s,r} + \sum_{j,s} T^e_{j,r,s}\right) \quad \forall r$$

-Investment

Demand function for commodities for investment uses

$$X^v_{i,r} = \frac{\lambda_{i,r}}{p^q_{i,r}}\left(S^p_r + S^g_r + \varepsilon_{USA,r} S^f_r\right) \qquad \forall i,r$$

-Armington composite good producing firm

Composite good production function

$$Q_{i,r} = \gamma_{i,r}\left(\delta^m_{i,r} M_{i,r}{}^{\eta_i} + \delta^d_{i,r} D_{i,r}{}^{\eta_i}\right)^{1/\eta_i} \qquad \forall i,r$$

Composite import demand function

$$M_{i,r} = \left(\frac{\gamma_{i,r}{}^{\eta_i} \delta^m_{i,r} p^q_{i,r}}{p^m_{i,r}}\right)^{\frac{1}{1-\eta_i}} Q_{i,r} \qquad \forall i,r$$

Domestic good demand function

$$D_{i,r} = \left(\frac{\gamma_{i,r}{}^{\eta_i} \delta^d_{i,r} p^q_{i,r}}{p^d_{i,r}} \right)^{\frac{1}{1-\eta_i}} Q_{i,r} \qquad \forall i,r$$

-Import variety aggregation firm

Composite import production function

$$M_{i,r} = \omega_{i,r} \left(\sum_s \kappa_{i,s,r} T_{i,s,r}{}^{\varpi_i} \right)^{1/\varpi_i} \qquad \forall i,r$$

Import demand function

$$T_{i,s,r} = \left(\frac{\omega_{i,r}{}^{\varpi_i} \kappa_{i,s,r} p^m_{i,r}}{(1+\tau^m_{i,s,r})\left[(1+\tau^e_{i,s,r})\varepsilon_{s,r} p^t_{i,s,r} + \tau^s_{i,s,r}\varepsilon_{USA,r} p^s\right]} \right)^{\frac{1}{1-\varpi_i}} M_{i,r} \quad \forall i,s,r$$

-Gross output transforming firm

i) For $i = PDR$ (paddy rice):

CET transformation function

$$Z_{i,r} + EMS_r = \theta_{i,r} \left(\xi^e_{i,r} E_{i,r}{}^{\phi_i} + \xi^d_{i,r} D_{i,r}{}^{\phi_i} \right)^{1/\phi_i} \qquad \forall i,r$$

Composite export supply function

$$E_{i,r} = \left(\frac{\theta_{i,r}{}^{\phi_i} \xi^e_{i,r} (1+\tau^z_{i,r}) p^z_{i,r}}{p^e_{i,r}} \right)^{\frac{1}{1-\phi_i}} (Z_{i,r} + EMS_r) \quad \forall i,r$$

Domestic good supply function

$$D_{i,r} = \left(\frac{\theta_{i,r}{}^{\phi_i} \xi^d_{i,r} (1+\tau^z_{i,r}) p^z_{i,r}}{p^d_{i,r}} \right)^{\frac{1}{1-\phi_i}} (Z_{i,r} + EMS_r) \quad \forall i,r$$

For simulation with Scenario S: Release of emergency stocks

$$EMS_r = \min\left\{\overline{EMS}_r, \max\left[(1-TFP_{i,r})Z^0_{i,r}, 0\right]\right\} \quad r = JPN$$

ii) For $i = TRS$ (transportation):

$$Z_{i,r} - TT_r = \theta_{i,r} \left(\xi^e_{i,r} E_{i,r}{}^{\phi_i} + \xi^d_{i,r} D_{i,r}{}^{\phi_i} \right)^{1/\phi_i} \qquad \forall i,r$$

$$E_{i,r} = \left(\frac{\theta_{i,r}{}^{\phi_i} \xi^e_{i,r} (1+\tau^z_{i,r}) p^z_{i,r}}{p^e_{i,r}} \right)^{\frac{1}{1-\phi_i}} (Z_{i,r} - TT_r) \quad \forall i,r$$

$$D_{i,r} = \left(\frac{\theta_{i,r}{}^{\phi_i} \xi^d_{i,r} (1+\tau^z_{i,r}) p^z_{i,r}}{p^d_{i,r}} \right)^{\frac{1}{1-\phi_i}} (Z_{i,r} - TT_r) \quad \forall i,r$$

iii) For $i \neq PDR, TRS$:

$$Z_{i,r} = \theta_{i,r} \left(\xi^e_{i,r} E_{i,r}{}^{\phi_i} + \xi^d_{i,r} D_{i,r}{}^{\phi_i} \right)^{1/\phi_i} \qquad \forall i,r$$

$$E_{i,r} = \left(\frac{\theta_{i,r}{}^{\phi_i} \xi^e_{i,r} (1+\tau^z_{i,r}) p^z_{i,r}}{p^e_{i,r}} \right)^{\frac{1}{1-\phi_i}} Z_{i,r} \qquad \forall i,r$$

$$D_{i,r} = \left(\frac{\theta_{i,r}{}^{\phi_i} \xi_{i,r}^{d} \left(1+\tau_{i,r}^{z}\right) p_{i,r}^{z}}{p_{i,r}^{d}} \right)^{\frac{1}{1-\phi_i}} Z_{i,r} \qquad \forall i,r$$

-Export variety producing firm
Composite export transformation function

$$E_{i,r} = \varsigma_{i,r} \left(\sum_{s} \rho_{i,r,s} T_{i,r,s}{}^{\varphi_i} \right)^{1/\varphi_i} \qquad \forall i,r$$

Export supply function

$$T_{i,r,s} = \left(\frac{\varsigma_{i,r}{}^{\varphi_i} \rho_{i,r,s} p_{i,r}^{e}}{p_{i,r,s}^{t}} \right)^{\frac{1}{1-\varphi_i}} E_{i,r} \qquad \forall i,r,s$$

-Inter-regional shipping sector[13]
Inter-regional shipping service production function

$$Q^{s} = c \prod_{r} TT_{r}{}^{\chi_r}$$

Input demand function for international shipping service provided by the r-th country

$$TT_{r} = \frac{\chi_r}{\left(1+\tau_{TRS,r}^{z}\right) \varepsilon_{r,USA} p_{TRS,r}^{z}} p^{s} Q^{s} \qquad \forall r$$

-Market-clearing conditions
Commodity market

$$Q_{i,r} = X_{i,r}^{p} + X_{i,r}^{g} + X_{i,r}^{v} + \sum_{j} X_{i,j,r} \qquad \forall i,r$$

Capital market

$$FF_{CAP,j,r} = F_{CAP,j,r} \qquad \forall j,r$$

Labor market

$$\sum_{j} FF_{LAB,j,r} = \sum_{j} F_{LAB,j,r} \qquad \forall r$$

$$p_{LAB,j,r}^{f} = p_{LAB,i,r}^{f} \qquad \forall i,j,r$$

Foreign exchange rate arbitrage condition

$$\varepsilon_{r,r'} \cdot \varepsilon_{r',s} = \varepsilon_{r,s} \qquad \forall r,r',s$$

Inter-regional shipping service market

$$Q^{s} = \sum_{i,r,s} \tau_{i,r,s}^{s} T_{i,r,s}$$

B.2 Distributions of Prices and Consumption

In the main text, we focused on the impact of productivity shocks and policies on welfare. As demonstrated in Figures 7 and 8, we can also compute the distributions of rice

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[13] For more information on the inter-regional shipping sector, see Hertel (1997).

price and consumption for Scenarios J0, J1, A0, and A1. However, we omit many of them so as to minimize the number of Figures included in the main text. For the referees' reference, we attach the omitted Figures below.

Figure B.1: Distribution of Processed Rice Consumption by the Household in Japan with Domestic-made Shocks
[unit: Quantity Index Calibrated to the Base Run Consumption Value in mil. USD]

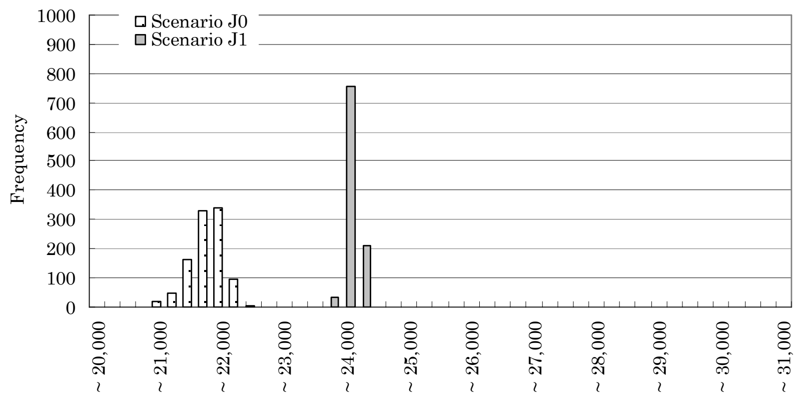


Figure B.2: Distribution of Processed Rice Consumption by the Household in Japan with Foreign- and Domestic-made Shocks
[unit: Quantity Index Calibrated to the Base Run Consumption Value in mil. USD]

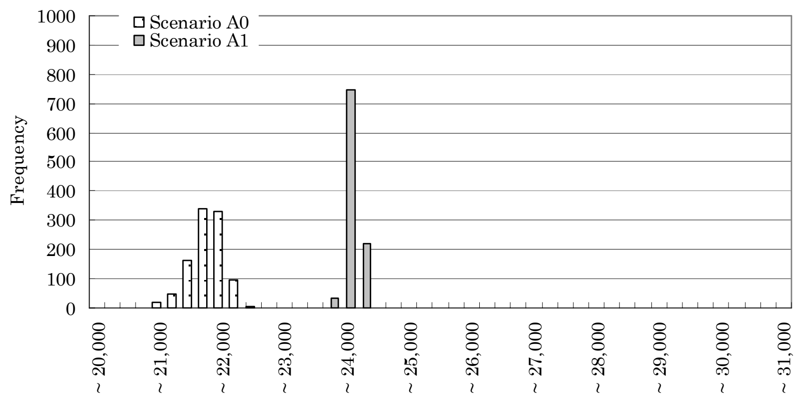


Figure B.3: Distribution of Processed Rice Price for Consumers in Japan with Domestic-made Shocks
[unit: Price Index Calibrated to the Base Run Price (=1.00)]

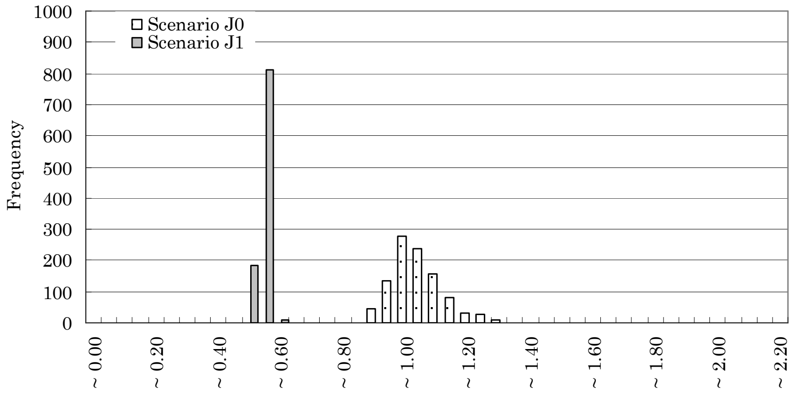
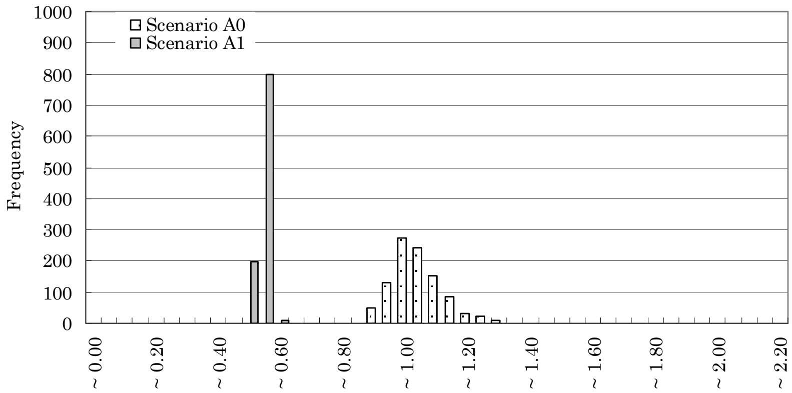


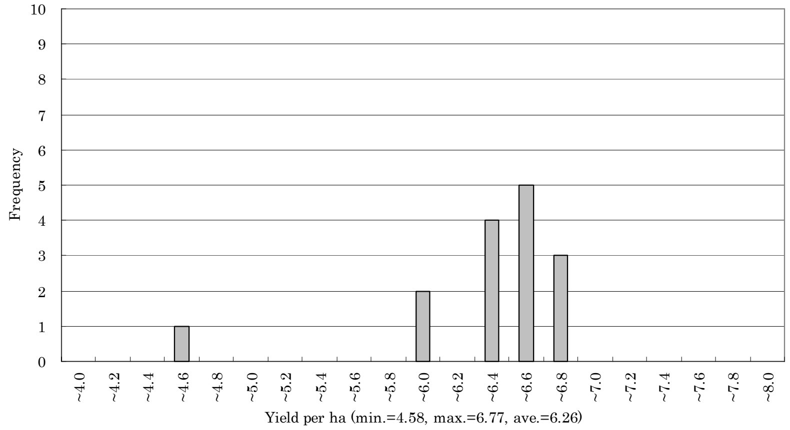
Figure B.4: Distribution of Processed Rice Price for Consumers in Japan with Foreign- and Domestic-made Shocks
[unit: Price Index Calibrated to the Base Run Price (=1.00)]



B.3 Monte Carlo Draws and Productivity Shocks

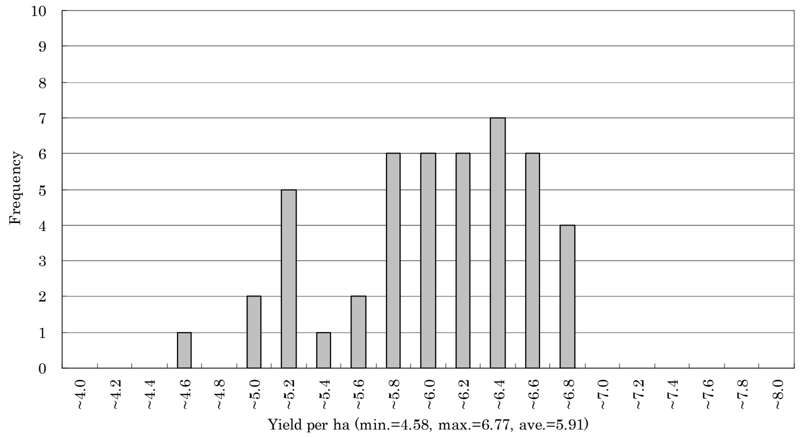
A question about our Monte Carlo simulation results could be made regarding our assumption about the distribution of productivity shocks. We plot the distribution of productivity for the sample period of our estimation (1990–2004) in Figure B.5 and for all the years available in FAOSTAT (1961–2004) in Figure 7, where the productivity distributions might not be found to follow a normal distribution. However, considering the upward-sloping trend of the productivity (Figure B.7), it is better to use the rice-crop index reported by MAFF to examine the distribution (Figure B.8). While there are two years (1945 and 1993) observed with extraordinarily low yields, the distribution looks normally distributed as the central limit theorem predicts.

Figure B.5: Distribution of Paddy Rice Productivity in Japan (1990–2004)
[unit: ton/hectare]



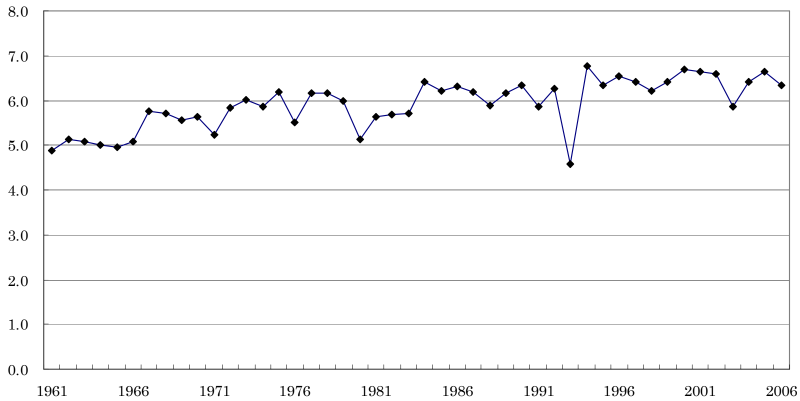
Source: FAOSTAT.

Figure B.6: Distribution of Paddy Rice Productivity in Japan (1961–2004)
[unit: ton/hectare]



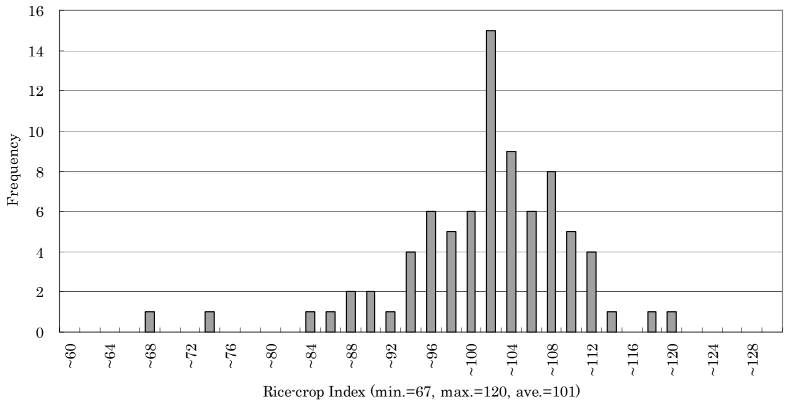
Source: FAOSTAT.

Figure B.7: Productivity of Paddy Rice Production in Japan
[unit: ton/hectare]



Source: FAOSTAT.

Figure B.8: Distribution of the Rice-crop Index in Japan (1926–2005)
[unit: average yield=100]



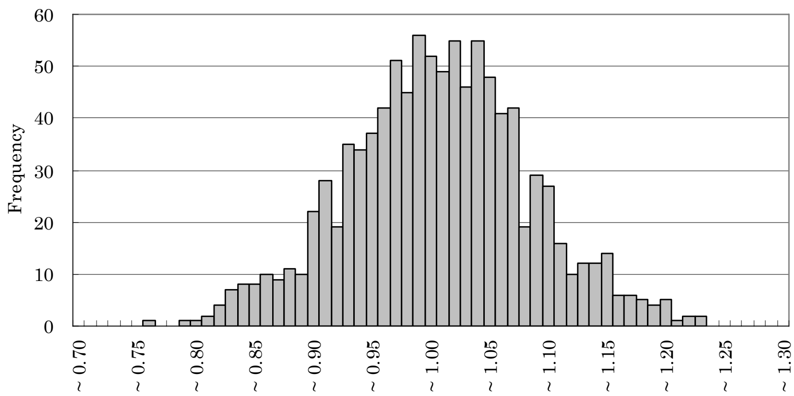
Source: MAFF, *Sakumotsu Tokei* [*Crop Statistics*].

Our Monte Carlo simulation generated random productivity shocks following i.i.d. $N\left(1, \sigma_r^{\ 2}\right)$ (Table B.2, Figure B.9). The summary statistics shows that the means and standard deviations are consistent with our original assumption discussed in the main text.

Table B.2: Summary Statistics of the Randomized Productivity

	Min.	Max.	Mean	S.D.
Japan	0.75	1.31	1.00	0.08
China	0.91	1.08	1.00	0.03
India	0.87	1.16	1.00	0.04
Indonesia	0.94	1.07	1.00	0.02
Bangladesh	0.84	1.13	1.00	0.05
Vietnam	0.95	1.05	1.00	0.02
Thailand	0.89	1.10	1.00	0.03
Philippines	0.83	1.16	1.00	0.05
US	0.86	1.11	1.00	0.04
Australia	0.74	1.25	1.00	0.09
Rest of Asia	0.94	1.07	1.00	0.02
Other Countries	0.93	1.08	1.00	0.02

Figure B.9: Distribution of the Randomized Productivity for Japan ($TFP_{PDR,JPN}$)



In our analysis, we did not consider any spatial correlations of productivity between regions. To justify this assumption, we examined the correlations among the residuals of the OLS model (i.e., the productivity shocks) shown in Table 5. Tables B.3 and B.4 do not indicate that the spatial correlations have something to do with the distance or adjacency between regions.

Table B.3: Correlation between the OLS Residuals

	China	India	Indonesia	Bangladesh	Vietnam	Thailand	Philippines	Japan	US	Australia	Rest of Asia	Other Countries
China	–											
India	0.0	–										
Indonesia	-0.5	-0.2	–									
Bangladesh	-0.5	-0.2	0.1	–								
Vietnam	-0.3	-0.4	0.5	0.1	–							
Thailand	-0.1	-0.1	0.2	-0.2	-0.2	–						
Philippines	-0.7	-0.2	0.7	0.5	0.6	-0.1	–					
Japan	0.2	-0.2	-0.2	-0.2	-0.1	0.2	-0.1	–				
US	-0.7	-0.2	0.7	0.2	0.3	0.3	0.8	0.2	–			
Australia	-0.2	0.2	-0.4	0.3	-0.2	-0.2	0.0	-0.0	-0.3	–		
Rest of Asia	-0.6	-0.0	0.3	0.5	0.2	0.2	0.5	-0.4	0.5	-0.1	–	
Other Countries	0.1	-0.1	0.2	0.3	-0.0	-0.2	0.2	0.1	0.1	-0.3	-0.2	–

Table B.4: Correlation between the OLS Residuals [only for |r|>0.5]

	China	India	Indonesia	Bangladesh	Vietnam	Thailand	Philippines	Japan	US	Australia	Rest of Asia	Other Countries
China	–											
India		–										
Indonesia	-0.5		–									
Bangladesh				–								
Vietnam					–							
Thailand						–						
Philippines	-0.7		0.7		0.6		–					
Japan								–				
US	-0.7		0.7				0.8		–			
Australia										–		
Rest of Asia	-0.6						0.5		0.5		–	
Other Countries												–